AIRSTRIP PAVING MATERIALS

UNIVERSITY OF MICHIGAN

JAN 2 8 1959

MAIN READING ROOM

HEARINGS

BEFORE THE

SUBCOMMITTEE FOR SPECIAL INVESTIGATIONS

OF THE

COMMITTEE ON ARMED SERVICES

HOUSE OF REPRESENTATIVES

EIGHTY-FIFTH CONGRESS

SECOND SESSION

UNDER THE AUTHORITY OF

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HEARINGS HELD DECEMBER 2 AND 5, 1958

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UNIVERSITY OF MICHIGAN
JAN 2 8 1959
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AIRSTRIP PAVING MATERIALS

TUESDAY, DECEMBER 2, 1958

HOUSE OF REPRESENTATIVES,
COMMITTEE ON ARMED SERVICES,
SPECIAL SUBCOMMITTEE FOR INVESTIGATIONS,
Washington, D. C.

The subcommittee met at 10 a. m., Hon. F. Edward Hébert (chairman of the subcommittee) presiding.

Mr. HÉBERT. The committee will be in order.

The Chair desires to make the following statement:

The subject of airstrip paving materials and, apparently, a preference for portland-cement concrete by the Air Force, to the exclusion of other materials, has been receiving the attention of this subcommittee and its predecessor subcommittees since February 1954. The first inquiry on this subject was conducted in the 83d Congress by our predecessor subcommittee, then headed by my colleague from Ohio, Hon William E. Hess, as chairman.

At that time, it had come to the attention of the subcommittee that the Department of the Air Force had, on alternate bids for rigid and flexible pavements, authorized a premium differential of 5 percent in favor of concrete. This 5 percent was computed by lumping a number of items together, including the runway strip, and making award at an increase of 5 percent where a concrete runway strip was offered.

Open hearings were held February 3, 4, 5, and 8, 1954. That subcommittee rendered its report on May 21, 1954. The subcommittee concluded, unanimously, that the use of all concrete in critical areas such as paving, runway landing ends, warming-up aprons, and areas around tanks and the like, be constructed of concrete. But it concluded that on the noncritical areas, particularly the long runways, that cement and flexible pavement should be considered without a price premium and on a direct comparison of first costs.

This report was sent to the Department of the Air Force May 25, 1954. After an exchange of correspondence, on August 16, 1954, the Department of the Air Force agreed that while it was completely convinced that portland cement has a definite advantage as compared to other materials, the Air Force had been unable to collect adequate engineering backup reflected by maintenance costs to substantiate this view. At that time, the Department of the Air Force suspended premium payments for cement concrete. This was in accordance with views expressed by the subcommittee.

Thereafter, in the noncritical areas which I have described, alternate specifications and bids were sought for both rigid and flexible pavements. Awards were made on a competitive basis without premium preference.

In the succeeding years, it was found that the price of concrete cement construction not only became competitive in price after the removal of the price differential, but it actually dropped an average of 4 percent in price. The subcommittee estimated that the total savings on the runway paving program would have approximated $50 million.

The criteria of August 16, 1954, was followed until some time in 1956. At that time it came to the attention of the subcommittee that the criteria of alternate specifications between flexible and rigid-type pavement for runway paving had been abandoned. In February 1956, the Chief of Air Installations advised the House Appropriations Committee that the Air Force was "essentially operating a concrete paving program, especially in the United States." As a result, substantially all competitive criteria was abandoned.

This subcommittee held hearings on June 24 and on July 3, 1957, during which time the whole subject was explored. Representations made at that time by the Air Force were, that the increased loads of the B–52, amounting to something in excess of 250,000 pounds, or nearly 2½ times that of the B–47, required this change in taxiways and runways.

The testimony on the subject was inconclusive. On August 14, 1957, the subcommittee issued its report. At that time, agreement had been reached that suitable testings of competitive materials would be undertaken in the fall of 1957, and the results reported to the subcommittee.

In its report of August 14, 1957, the subcommittee said:

> Pending this determination, we repeat the caution previously expressed concerning any extensive Air Force building program excluding less costly material and design alternate.

At that same time, the subcommittee announced that when the Corps of Engineers test was completed, the subcommittee would consider Navy criteria for its runway paving requirements. The subcommittee observed that the Navy problems did not appear to be "as critical nor of the magnitude of the Air Force problem."

The subcommittee convened on January 9, 1958, and received a report on developments following the August 1957 hearing. This material is collected in part II of the hearings on this subject, published February 14, 1958.

The test now for consideration was prepared and conducted by the Corps of Engineers in collaboration with the Department of the Air Force, and under the observation of interested parties, at Columbus, Miss., Air Force Base.

The results of that test and some findings were presented to the subcommittee in November 1958. That report has been disseminated to all persons participating in the hearings or who have otherwise manifested an interest in the subject.

In the interval, we learn that the Department of the Navy conducted an independent inquiry, and issued a report which came, accidentally, into the hands of the subcommittee, in May 1958.

These two reports will be the subject of this hearing which commences this morning.

It is the purpose of the subcommittee to have its findings and recommendations ready for the 86th Congress. The only time available for Members is this week.

Unfortunately, some interested persons have other engagements which conflict with this date; and to afford the maximum accommodation while adhering to our scheduled requirements, we will hear the Government testimony today and recess this particular hearing until Friday afternoon, December 5, at 2 p. m., at which time we will receive the comment or testimony of persons desiring to be heard on the conclusions reached by these services.

This morning our witnesses will be headed by Maj. Gen. Walter K. Wilson, Jr., Deputy Chief of Engineers for Construction, and Brig. Gen. Edward Brown, Assistant Chief of Military Construction, who appears with him.

The Department of the Navy will be represented by the Chief of the Bureau of Yards and Docks, or his designee.

Mr. John Ferry, Deputy Chief for Installations of the Department of the Air Force, which Department has collaborated in the tests for the Corps of Engineers, is here for the Department of the Air Force, to comment.

General Wilson, I understand you have a prepared statement, and we will hear you.

Mr. COURTNEY. One observation, Mr. Chairman.

Mr. HÉBERT. Yes.

Mr. COURTNEY. Mr. Chairman, upon the receipt of the report of the tests which were conducted and about which General Wilson will testify, the subcommittee received copies, and at the request of the subcommittee the Corps of Engineers forwarded to all interested parties who had recorded and appeared and testified copies of that report. That occurred some 2 weeks ago, at the announcement of this hearing.

We have received responses from the Asphalt Institute, from the Portland Cement Association, and from the National Bituminous Concrete Association, as well as from several Engineering Corps, from the Association of General Contractors, who indicate that they do not desire to be heard, and from the Shell Oil Co., which is in some way interested in the test at Columbus.

At the same time, a similar request was made that the Navy Department forward its report and findings to all interested parties on the list left the subcommittee.

The general has a prepared statement, Mr. Chairman.

STATEMENT OF MAJ. GEN. WALTER K. WILSON, JR., DEPUTY CHIEF OF ENGINEERS FOR CONSTRUCTION

General WILSON. I have a prepared statement, sir.

Mr. Chairman, at the conclusion of the July 3, 1957, hearings before this committee I testified that I was confident that the Corps of Engineers could build flexible runway interior pavements that would satisfactorily support the operations of B–52 aircraft. Following instructions of the committee, the Chief of Engineers of the Department of the Army and the Director of Installations of the Department of the Air Force jointly developed a plan for an accelerated traffic test on flexible runway interior pavements at Columbus Air Force Base for the purpose of demonstrating this capability.

Traffic tests at Columbus were accomplished in accordance with the plan outlined to the committee by General Brown in January

1958. The test pavements were subjected to as many traffic-loading repetitions as B–52 aircraft operation would normally produce in 20 years. The tests were completed during September 1958.

The results of these tests have been analyzed by pavement engineers of my staff and incorporated into a final report, which I will submit for the record at this time.

From this report and from observations of the condition of the test pavements at the conclusion of the traffic tests, the Corps of Engineers has drawn the following conclusions:

1. Considering normal B–52 operations only, we have concluded that the tests at Columbus Air Force Base demonstrated the validity of the design and construction procedures developed by the Corps of Engineers for heavy-load flexible runway interior pavements.

2. Runway pavements must, however, be capable of supporting incidental periods of B–52 taxi operation in addition to the normal landing and takeoff traffic. The tests indicated that objectionable differential settlement could possible develop on runways where taxi operations are extended over a period of 6 months or longer.

3. The flexible-pavement surface in the immediate vicinity of the buried-slab transition between the flexible and rigid pavement sections developed a five-eighth inch depression across the width of the traffic test lane.

4. An average 1¼-inch subsidence of the flexible pavement in the traffic lane, combined with a peculiarity of the test traffic pattern, resulted in excessive differential settlement between the trafficked area and the nontrafficked area to either side. The abrupt change in surface elevation would not be expected under normal B–52 operations but would be a possibility under extended taxi operations.

5. The surface smoothness within the traffic lane itself after completion of the test complied essentially with the smoothness tolerance allowed during construction.

6. The Corps of Engineers feels that the pavements were designed and constructed under as representative conditions as possible considering the unusually large number of sidewalk superintendents from both Government and industry.

7. The test was not intended to show an economic comparison between rigid and flexible pavement. Any such comparison based upon experience at Columbus Air Force Base would have little worldwide application. As I stated in the hearings last year, local conditions will determine the economics.

8. The test was conceived and planned to establish the capability of flexible runway interior pavements only. The Corps of Engineers has not altered its position that primary taxiways and runway ends on heavy load airfields should be constructed of rigid pavement except in exceptional geographic areas.

9. The Corps of Engineers has concluded that it is possible to construct heavy load flexible runway interior pavement that will provide adequate service for normal B–52 operation. However, B–52 operational conditions may occur that could cause objectionable roughness in flexible pavement because of differential settlement. Therefore, as a general policy, we are in agreement with the Air Force that a center strip of rigid pavement in runway interiors is good insurance.

In these conclusions, gentlemen, you will find only two areas of

qualification with regard to overall adequacy of the test pavements. First, I am not satisfied that the present buried slab transition between the rigid and flexible pavements will provide satisfactory or necessary smoothness. While an improved transition should be possible, I would point out that adequate smoothness could be restored to the transition at Columbus in less than 1 day for about $200; and if this condition were projected to both ends of a typical runway, smoothness could be restored in 1 day for about $1,000. This minor maintenance work could be accomplished at the same time that the joints in the adjacent rigid pavements were being resealed.

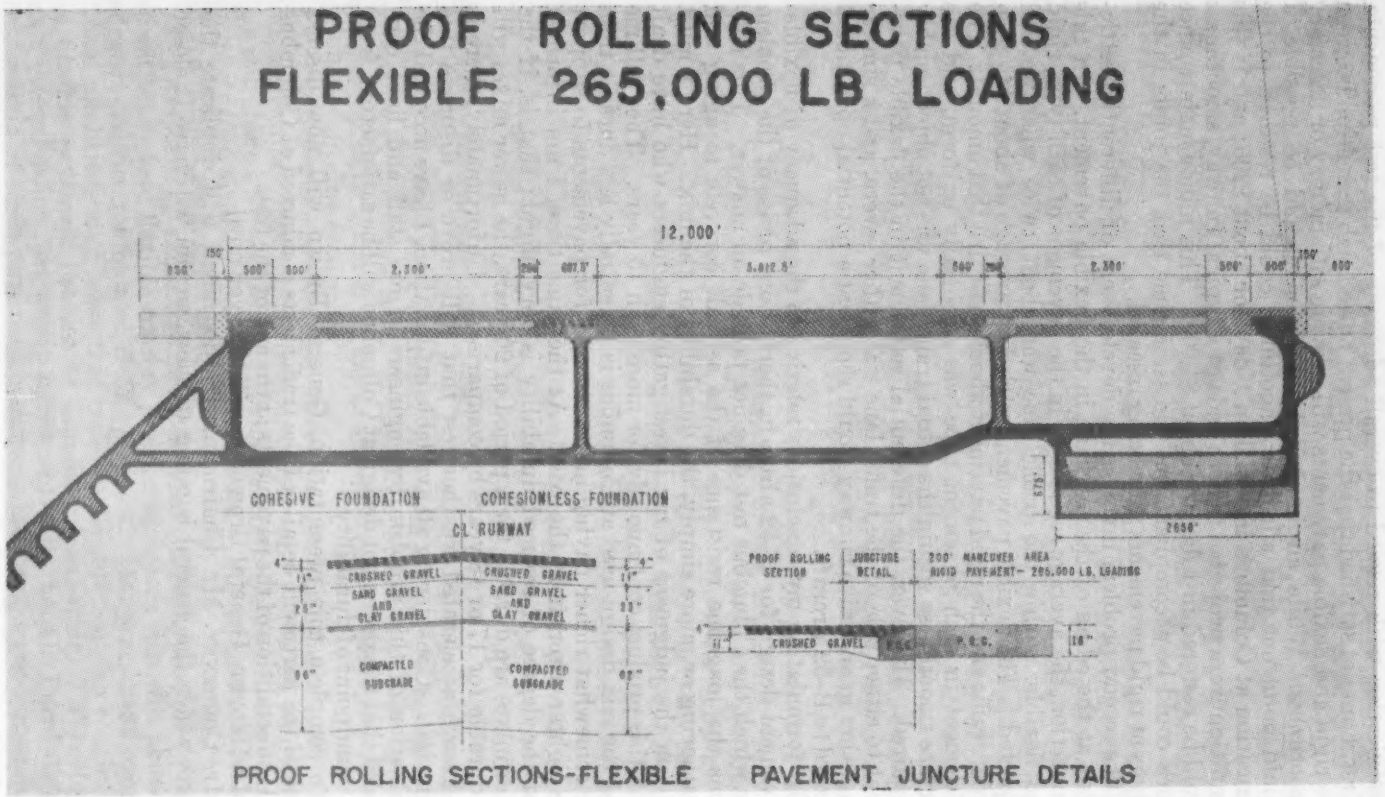
The second problem involves the development of differential settlement at the edges of the test lane in the flexible pavement. In this connection, the average settlement in the pavement of each type, rigid and flexible, within the traffic lane was about twice what we had expected. The flexible pavement settled an average of about 1¼ inch under traffic and the rigid pavement about one-third that amount. The settlement in each pavement type was essentially uniform, and the surface smoothness within the actual traffic lane was not objectionably impaired. However, the differential settlement in the flexible pavement to either side of the traffic lane was rather severe, and a similar condition in an active runway would represent a potential operational hazard to B–52 aircraft.

In formulating my conclusions relative to the adequacy of flexible-pavement design for B–52 aircraft, there is one phase of the problem for which the Columbus test does not provide an answer. This concerns the longtime resistance of the asphalt concrete to aging and weathering or, more simply, the durability of the mix. Here I must rely on the judgment of my investigating engineers who have dealt with this product continuously for more than 15 years. They tell me that the mix design used at Columbus is potentially less durable than the somewhat richer paving mixtures used for pavements to support the lighter aircraft in the past. At the same time, I am informed that the degree of reduced durability is very slight; that is, if the older mixes are durable for a period of 20 years, the newer mixes will be durable for 17 or 18 years by comparison. Unfortunately, there is no known accelerated weather test that will prove or disprove this appraisal. Considering all available information, I have accepted the evaluation of this problem by engineers of my staff and have concluded that the pavement design at Columbus will be satisfactory from the standpoint of durability.

To complete this presentation, General Brown will now discuss some of the pertinent details of the traffic tests conducted at Columbus and the condition of the pavements at the end of the test.

Mr. HÉBERT. General Brown, we will hear you now.

Mr. COURTNEY. Mr. Chairman, this document will duplicate the charts which the general is going to show, so you will have it closer at hand.


PROOF ROLLING SECTIONS
FLEXIBLE 265,000 LB LOADING
12,000'
COHESIVE FOUNDATION
COHESIONLESS FOUNDATION
CL RUNWAY
CRUSHED GRAVEL
SAND GRAVEL AND CLAY GRAVEL
COMPACTED SUBGRADE
PROOF ROLLING SECTION
JUNCTURE DETAIL
200' MANEUVER AREA
RIGID PAVEMENT- 265,000 LB. LOADING
CRUSHED GRAVEL
P.C.C.
PROOF ROLLING SECTIONS-FLEXIBLE
PAVEMENT JUNCTURE DETAILS

STATEMENT OF BRIG. GEN. EDWARD BROWN, ASSISTANT CHIEF OF MILITARY CONSTRUCTION

General BROWN. Mr. Chairman, my first chart shows the location of the two proof-test sections within the interior of the runway at Columbus Air Force Base. These pavements were designed for the new 265,000-pound landing-gear loading of the B–52G aircraft, whereas the design of the remaining pavements at this base was based on the 240,000-pound landing-gear loading of previous B–52 models.

Construction of the test sections was observed by a number of representatives of industry and Government other than those directly associated with construction at this base. I would like to enter into the record a list of these visitors and the organization which they represent.

Mr. HÉBERT. They will be made part of the record.

(The document referred to is as follows:)

LIST OF GOVERNMENT AND INDUSTRY REPRESENTATIVES WHO VISITED THE PROOF-TEST SECTION AT COLUMBUS AIR FORCE BASE, MISS.

OFFICE OF THE CHIEF OF ENGINEERS

Maj. Gen. W. K. Wilson, Jr.
Brig. Gen. E. A. Brown, Jr.
Maj. R. J. Shreder
Maj. H. R. Stansbury
K. M. Christinson
F. B. Hennion
A. S. Kurtz
Herman Orr
T. B. Pringle
W. C. Ricketts
J. P. Sale
J. C. Suter

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Col. G. H. Andrews
Col. R. I. Barronclough
Col. J. L. McKnight
Col. G. N. Payne
Capt. M. B. Miraglia
F. P. Dahl
P. P. Menzie

HEADQUARTERS, 2D AIR FORCE

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O. P. Otterson
E. C. Reid
B. R. Roberts, Jr.

HEADQUARTERS, UNITED STATES AIR FORCE

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Col. J. G. McDonald
Lt. Col. H. W. Houston
Lt. Col. C. W. Sampson
J. M. Ferry
Col. H. K. Kelley
F. W. Kerley
R. D. Marlow
G. W. Leslie

OFFICE, ASSISTANT SECRETARY OF DEFENSE (PROPERTY AND INSTALLATIONS)

U. E. Lord

OFFICE OF THE AFIR, SOUTH ATLANTIC REGION

Col. F. S. Jessie
Col. W. E. Johnston
Lt. Col. E. Blevins
Lt. Col. R. J. Harrison
W. O. Harrell
A. C. Monroe
E. C. Tompkins

UNITED STATES ARMY ENGINEER DIVISION, SOUTH ATLANTIC

Maj. Gen. F. M. Albrecht
Maj. T. H. Lawrence, Jr.
Maj. R. H. Middleton
R. E. Beatty
R. G. Beckwith
W. V. Conn
H. F. Lawson
C. P. Lindner
Monte MacFarland
G. H. Mittendorf
G. G. Peterson
G. C. Reed, Jr.
P. B. Schultz
Mike Smith
O. B. Stewart
M. C. Webster

LIST OF GOVERNMENT AND INDUSTRY REPRESENTATIVES WHO VISITED THE PROOF-TEST SECTION AT COLUMBUS AIR FORCE BASE, MISS.—Continued

SOUTH ATLANTIC DIVISION LABORATORY

Gerald Joiner
K. W. Schwartz
D. D. Tabb

UNITED STATES ARMY ENGINEER DISTRICT, MOBILE

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Col. H. E. Bisbort
Col. R. O. Miller
Maj. J. T. Boyd
H. L. Fuller
J. R. Ingram
A. V. Kelly
W. C. Knox
J. H. Lamar
W. M. Leslie
W. L. Little
E. M. Moore
F. A. Robeson
G. A. Satterwhite
B. W. Stewart
S. D. Waggener
J. E. Watkins

WATERWAYS EXPERIMENT STATION

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Col. A. P. Rollins, Jr.
H. B. Boyd
J. C. Bunyard
C. D. Burns
W. H. Crawford, Jr.
C. R. Foster
J. D. Garnett
A. H. Joseph
M. J. Mathews
A. A. Maxwell
O. B. Ray
L. L. Steen
W. J. Turnbull
G. W. Vinzant
L. M. Womack

OHIO RIVER DIVISION LABORATORIES

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P. F. Carlton
R. L. Hutchinson

CONSULTANTS, OCE

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R. E. Fadum, North Carolina State University
F. S. Gilmore
W. H. Goetz, Purdue University
J. L. Land
O. J. Porter
K. B. Woods, Purdue University

CONSULTANTS, AIR FORCE

John C. B. Elliott

CIVIL AERONAUTICS AUTHORITY

V. S. Meissner

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Major W. C. Foreman

THE ASPHALT INSTITUTE

J. E. Buchanan
J. B. Dunbar
C. A. McKeogh
A. S. Wellborn

PORTLAND CEMENT ASSOCIATION

H. R. Addison
A. A. Anderson
A. R. Brickler
J. P. Burnell
D. L. Chaney
F. M. Chapman, Jr.
W. C. Forsyth
R. W. Gillette
R. S. Gordon
G. D. Kennedy
G. K. Ray
J. L. Walker
W. G. Westall

LIST OF GOVERNMENT AND INDUSTRY REPRESENTATIVES WHO VISITED THE PROOF-TEST SECTION AT COLUMBUS AIR FORCE BASE, MISS.—Continued

SHELL OIL CO.

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J. J. Heitham
W. Heukelom
J. O. Izatt
W. C. Lehigh
C. T. Metcalf
H. W. Miesman

AMERICAN BITUMEN & ASPHALT CO.

J. C. Waiting

NATIONAL BITUMINOUS CONCRETE ASSOCIATION

H. K. Griffith
S. B. Hudson
J. B. Kelly
Fritz Leffingwehl
W. H. Mills

ESSO STANDARD OIL CO.

E. J. Bolivar
W. F. Dahl
M. R. Lang

UNITED STATES BUREAU OF PUBLIC ROADS

C. A. Bergey
H. W. Rex

SOUTHLAND CO.

Clyde Walters

BROTHERS, INC.

E. E. Kirwan

MID-STATE PAVING CO.

T. H. Webb

ALLIED EQUIPMENT

Tom Hannsford

A. A. BUSH CO.

J. Carmichael

R. G. FOSTER CO.

R. G. Foster, Jr.
F. M. Walton

WARREN BROS. ROADS CO.

C. H. Ciehaufman
R. B. Dungin
T. L. Hayslett
N. W. E. Long

GOODWIN ENGINEERS OF THE SOUTH

S. B. Perry

UNIVERSITY OF ILLINOIS

J. W. Hutchinson

4228 AB GROUP

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Lt. W. S. Anderson
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R. J. Schneller
C. S. Showell

CALIFORNIA RESEARCH CORP.

T. C. Hein

MISSISSIPPI STATE HIGHWAY DEPARTMENT

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H. E. Smith
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H. O. Thompson
J. K. Toland

FLORIDA-GEORGIA TRACTOR CO.

J. B. Webster

FLORIDA LIMEROCK INSTITUTE

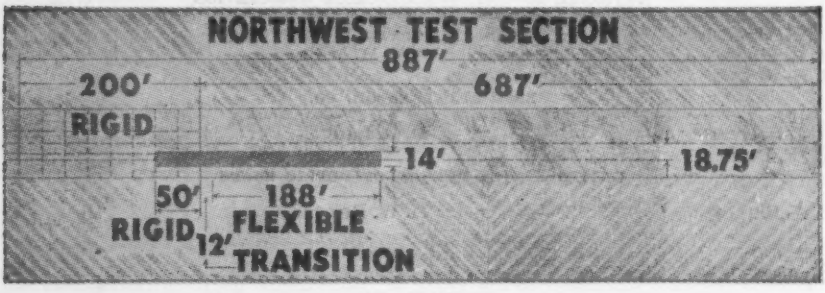
E. A. Logan

AMMANN AND WHITNEY

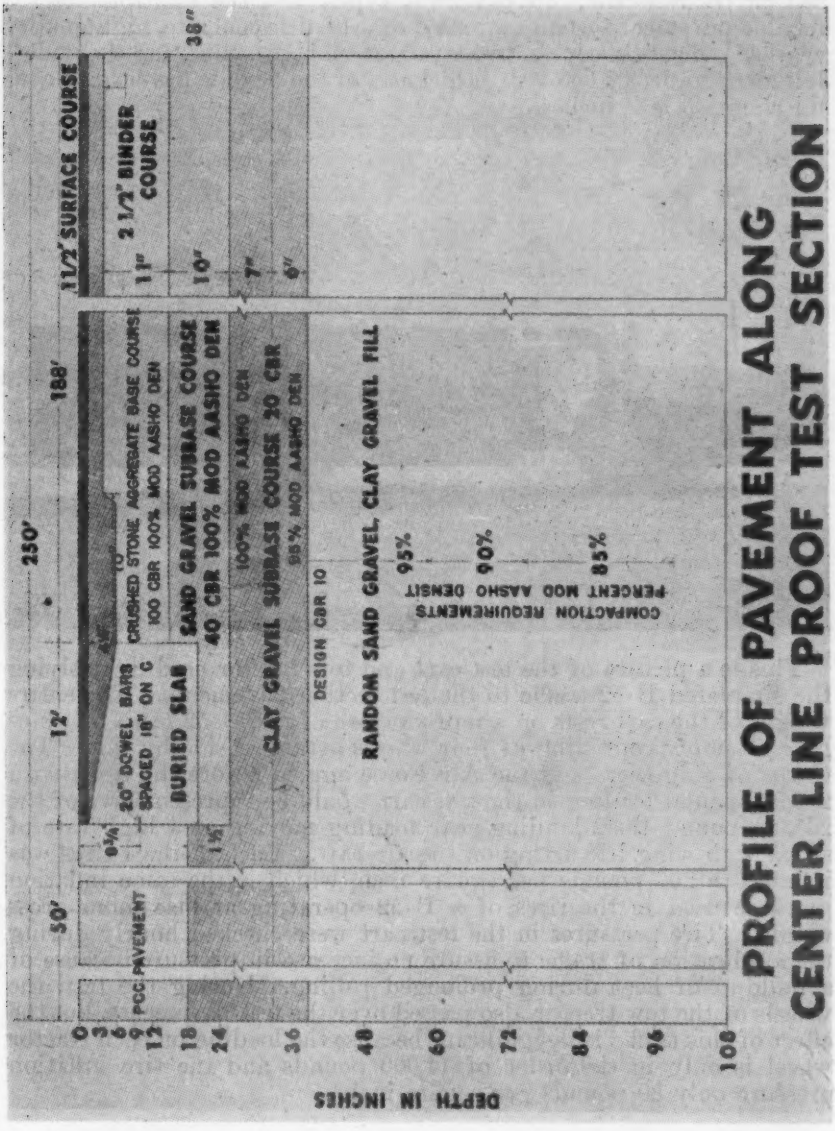
V. Obrcian

General BROWN. Construction of the test sections was completed on August 25, 1958.

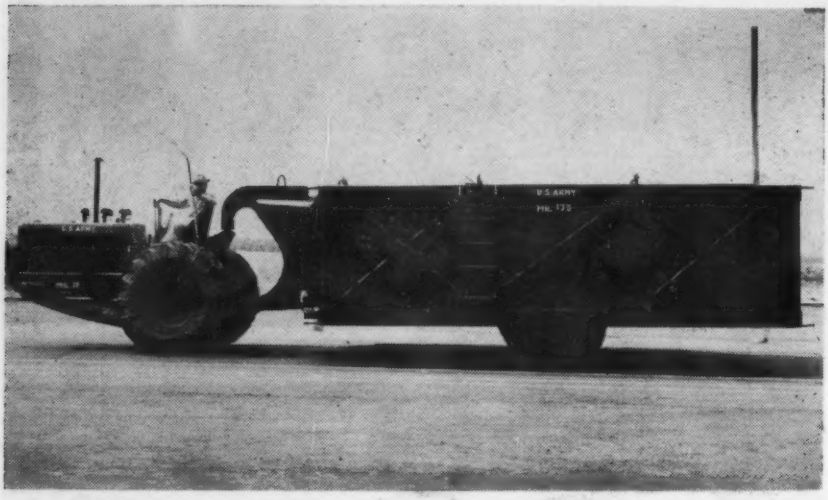
Selection of the actual lane to be proof rolled was made by the Air Force. The Director of Installations recommended that the test traffic be applied "on the northwest test section along the line midway between the runway centerline and the west edge of the test section"—the test area to include the flexible pavement and the transition between the flexible pavement and the rigid-pavement maneuver area.



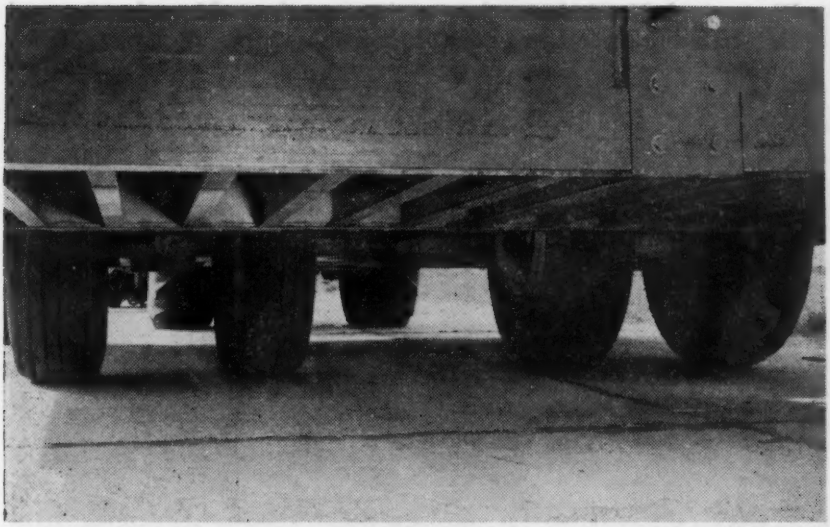
This chart (2) illustrates the location of the test lane in conformance with the Air Force recommendation. The overall length of the test lane over which test traffic was applied was 250 feet. This included 50 feet on the rigid pavement, 12 feet over the transition, and 188 feet on the flexible pavement.


PROFILE OF PAVEMENT ALONG
CENTER LINE PROOF TEST SECTION
DEPTH IN INCHES
0
3
6
9
12
18
24
36
48
60
72
84
96
108
50'
12'
250'
188'
PCC PAVEMENT
20" DOWEL BARS SPACED 18" ON C
BURIED SLAB
CRUSHED STONE AGGREGATE BASE COURSE
100 CBR 100% MOD AASHO DEN
SAND GRAVEL SUBBASE COURSE
40 CBR 100% MOD AASHO DEN
100% MOD AASHO DEN
CLAY GRAVEL SUBBASE COURSE 20 CBR
95% MOD AASHO DEN
DESIGN CBR 10
RANDOM SAND GRAVEL, CLAY GRAVEL FILL
COMPACTION REQUIREMENTS
PERCENT MOD AASHO DENSIT
95%
90%
85%
1 1/2" SURFACE COURSE
2 1/2" BINDER COURSE
11"
10"
7"
6"
38"

The next chart (3) shows a longitudinal section of the pavements in the test area. Here we see the 18-inch thickness of the portland-cement concrete in the rigid-pavement portion, the details of the buried-concrete slab with the overlying asphaltic concrete in the transition section between the two pavement types, and the multiple-layered flexible pavement system composed of asphaltic concrete, high-quality crushed-stone base course, two layers of subbase course, and the underlying subgrade. The overall thickness of the flexible pavement above the subgrade is 38 inches.

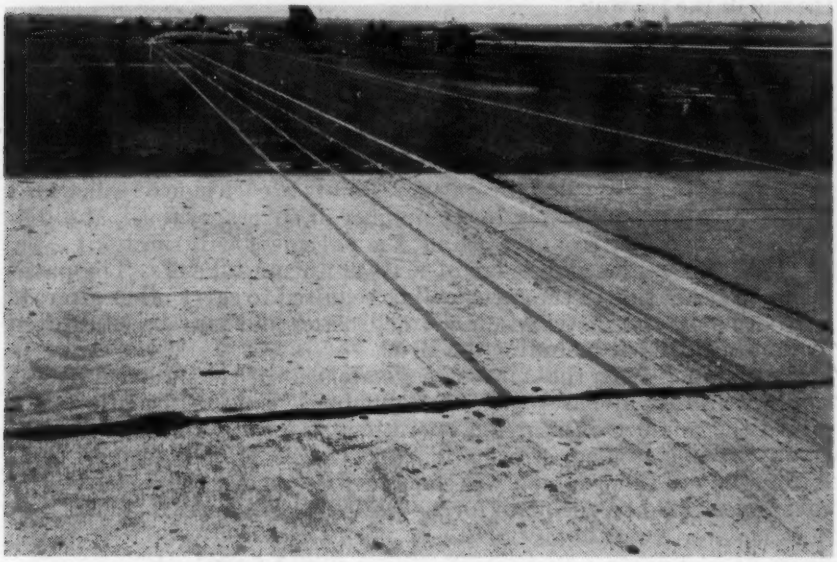


This is a picture of the test cart and tow tractor used in applying the simulated B–52 traffic to the test section pavements. The entire weight of the cart rests on a reproduction of one B–52 main landing-gear assembly consisting of four wheels arranged side by side. The Corps of Engineers and the Air Force agreed before the test that a 212,000-pound loading in the test cart would be representative of the 265,000-pound B–52 landing-gear loading moving at a high rate of speed with wing life acting on the aircraft. Each of the 4 tires was inflated to 266 pounds per square inch, which is the same inflation pressure used in the tires of a B–52 operating at maximum gross weight. Tire pressures in the test cart were checked hourly during the application of traffic to assure no increase in pressure because of a buildup of heat during prolonged rolling. During the test, the wheels of the tow tractor also passed over the test pavements, but the effect of this traffic is insignificant because the loading on each tractor wheel is only in the order of 14,000 pounds and the tire inflation pressure only 30 pounds per square inch.



Photograph No. 2 shows a closeup of the B–52 landing-gear assembly contained within the test cart. I will repeat, those are the same tires, inflated to the same pressure and spaced to the exact dimensions as one main landing gear on an operational B–52 aircraft.

The third photograph shows the test area with the actual traffic lane bounded by 2 paint stripes 14 feet apart and running some 250 feet from the rigid pavement onto the flexible pavement. The remaining lines, together with the first test lane boundary line, were used by the tractor operator to position the cart to give a uniform distribution of traffic across the test lane.



Photograph No. 4 shows the cart in operation. Note the arm and telltale hanging directly over one of the guide stripes.

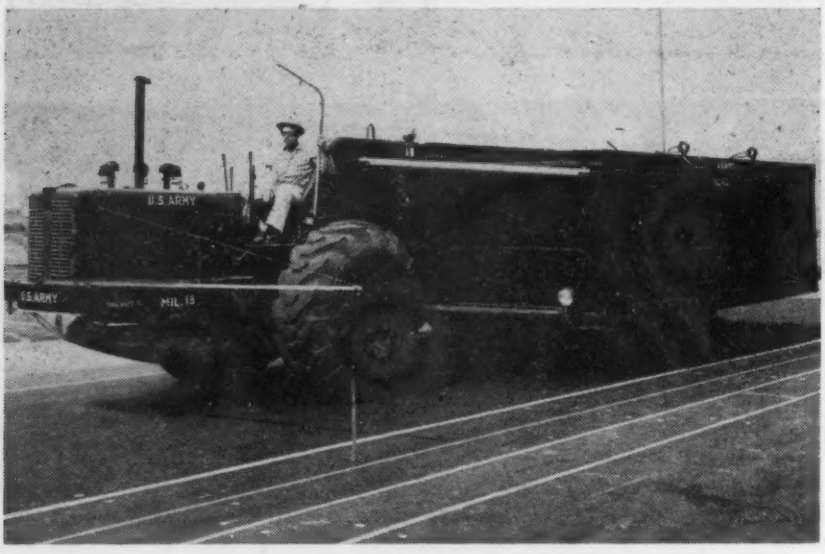
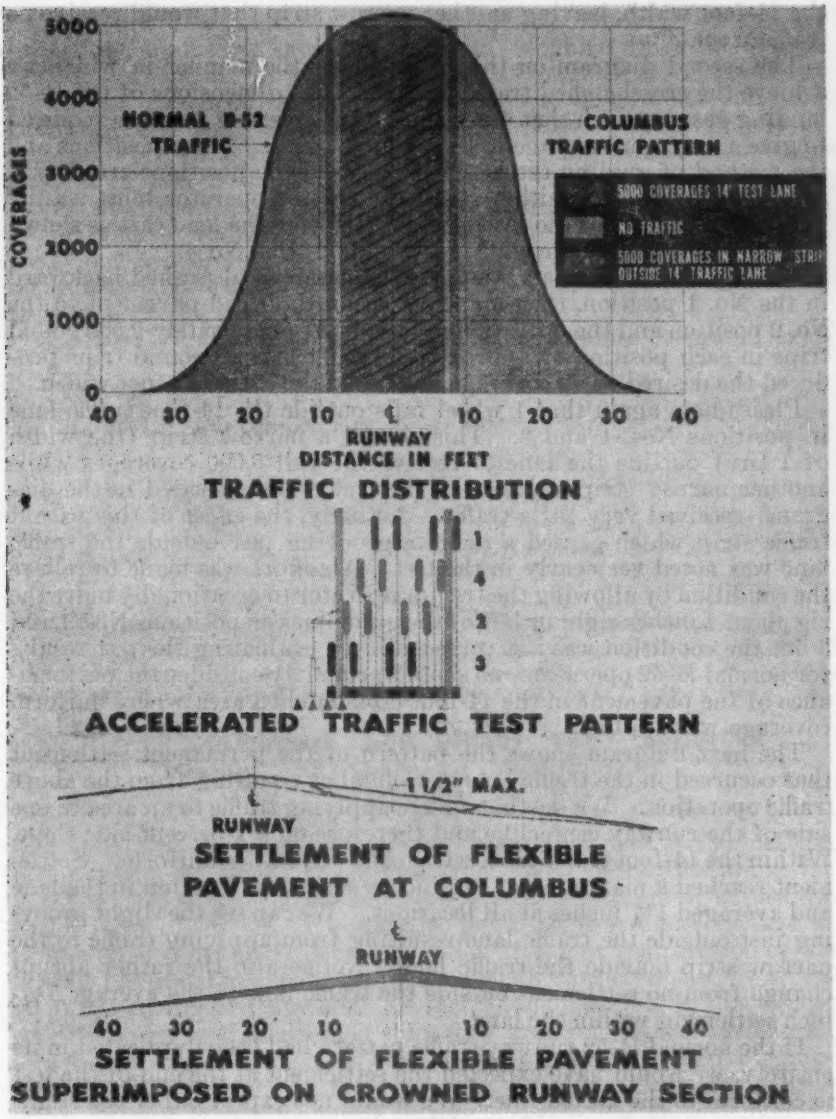


Chart 4: I will now show in more detail what we mean by such terms as traffic distribution and traffic coverages. In the top diagram we have shown the normal accumulation of B–52 traffic loadings on a runway-interior pavement with respect to the runway centerline. We can see that more operations occur directly over the centerline than over points to either side. This particular distribution obtains in the runway interior during takeoff operations at a distance of 1,000 feet from the end of the runway.

Specifically, the diagram shows the number of times each point across the runway-interior pavement will be traversed by a B–52 landing-gear tire in approximately 20 years of operation. When a point in the pavement has been loaded by direct contact with a tire, we say that point has received one coverage. Thus, in 20 years of B–52 traffic, each point in the center 20 feet of the runway will have received something in the order of 5,000 coverages. Points to each side of this width will receive a progressively lower number of coverages until, at a distance about 35 feet from the center, the pavement will rarely, if ever, be trafficked by the main gear of a B–52 during takeoff. The pavements to either side of the curve will be required to carry other aircraft with other lateral distribution characteristics and may be used often by landing aircraft including the B–52.

We obtained from the Air Force a statement of the intended operation of aircraft at bases such as Columbus. This information contained the number of expected operations and the weight of the aircraft. It is classified information and therefore is not given here. After study of these data, it was concluded that a design based on 5,000 coverages would be adequate for 20 years of the estimated traffic.



It was established before the tests that about 3 or 4 months of continuous traffic testing would be required to completely duplicate the actual distribution shown under the black line. So it was decided to duplicate only the center portion of the curve by giving a uniform 5,000 coverages to a 14-foot width of pavement.

The crosshatched plotting on this graph is the traffic distribution that was planned for the test. We can see that the 5,000 coverages were to be applied with no tapering of traffic to either side of the traffic lane as would normally occur. Because of the wheel spacing of the test-rig gear, traffic would also be applied to a narrow strip outside

the 14-foot width, leaving another narrow strip that would receive no traffic at all.

The second diagram on this chart shows the manner in which we achieve the crosshatched traffic pattern. The dimensions of the B–52 landing gear are such that 4 positions of the test-rig gear are required to give a uniform coverage to the 14-foot width. These positions and the method of guiding the load cart to yield the positions are shown. Note that to attain position No. 2 the tractor operator must simply hang the telltale over the second paint stripe. The load cart as shown in the preceding photograph No. 4 was in position No. 4.

During the test the cart was pulled forward and pushed backward in the No. 1 position, then maneuvered on the rigid pavement to the No. 2 position and the operation repated. Approximately 2,500 round trips in each position or approximately 10,000 total round trips produced the desired 5,000 coverage level over the entire 14-foot width.

Please note again that 1 wheel falls outside the 14-foot traffic lane in positions Nos. 1 and 3. This caused a narrow strip (the width of 1 tire) outside the lane to receive the full 5,000 coverages while another narrow strip adjacent to the traffic lane (shaded in the diagram) received very little traffic. Actually, the effect of this vacant traffic strip which caused a definite grooving just outside the traffic lane was noted very early in the test. An effort was made to relieve the condition by allowing the tractor operator to occasionally move the rig about 4 inches right or left of the guidelines on positions Nos. 1 and 3 but the condition was not corrected. In evaluating the test results for normal B–52 operation, we should primarily consider the performance of the pavement in the 14-foot crosshatched area where uniform coverage was applied.

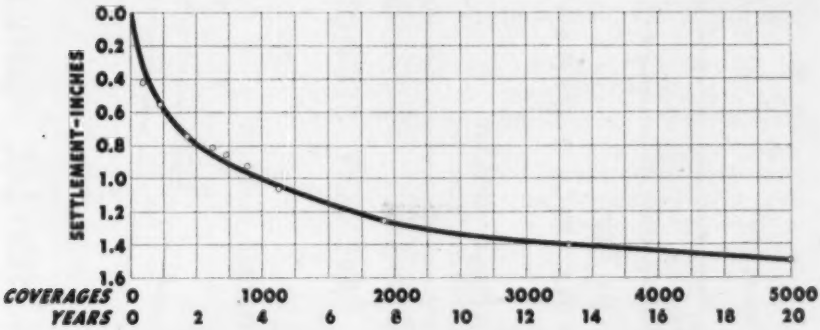
The next diagram shows the pattern of the permanent settlement that occurred in the traffic lane at Columbus resulting from the above traffic operation. We see that we are applying traffic to an area to one side of the runway centerline and therefore on a 1-percent side slope. Within the 14-foot traffic lane, settlement was rather uniform. Settlement reached a maximum of 1½ inches across the location in the lane and averaged 1¼ inches at all locations. We can see the slight grooving just outside the traffic lane resulting from applying traffic to the narrow strip outside the traffic lane. Notice also the rather abrupt change from no settlement outside the traffic lane to the average 1¼-inch settlement within the lane.

If the normal B–52 runway traffic pattern had been duplicated in its entirety, we would have expected the settlement at the end of the test to conform to the dotted line. We would not expect either the slight grooving or the abrupt differential settlement.

Again projecting our information, we know that the traffic distribution pattern would normally be centered at the crown along the runway centerline. Therefore, the settlement pattern as applied to a true prototype condition would be expected to look like the lower diagram. Here again we see no differential settlement at the edge of the traffic boundary. More likely we would have flattened the crown in the order of 1 to 1½ inches. In these lower two diagrams, we have exaggerated the vertical scale in order to show the settlement.

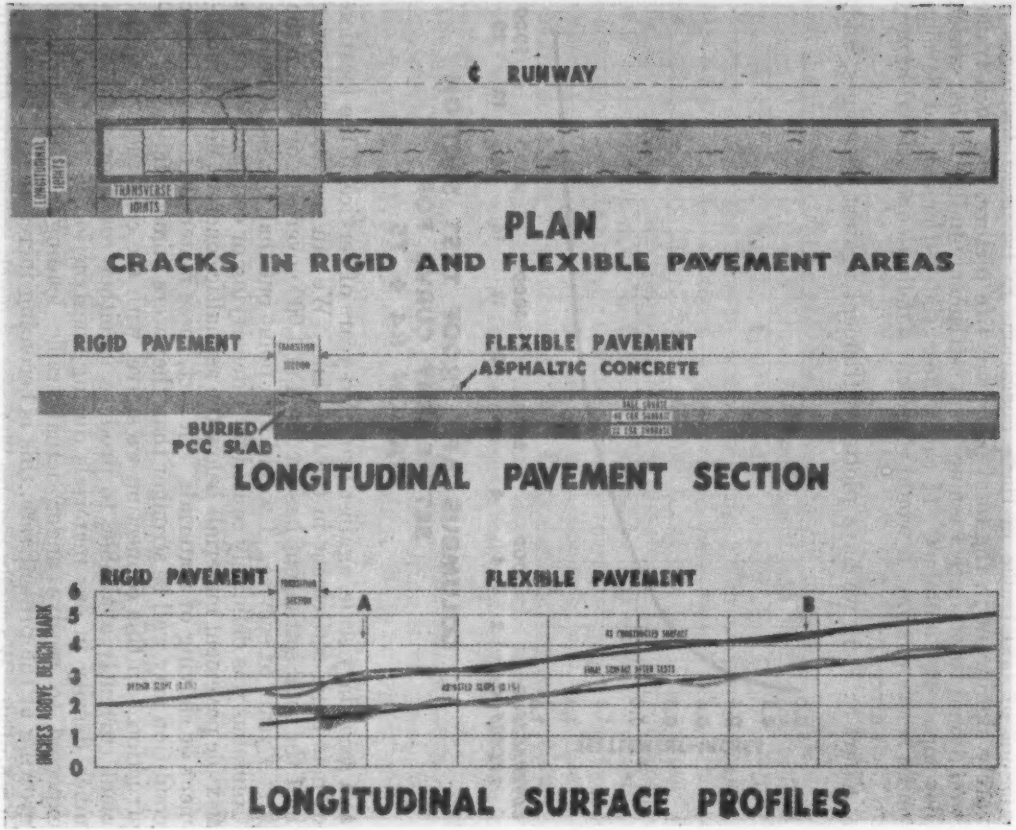
From this discussion. we can conclude that normal B–52 runway operations would not create detrimental roughness in a heavy-load flexible runway interior pavement. It is a fact, however, that runway pavements at many Air Force bases must undergo an incidental taxi-traffic operation. These occasions come about while a runway is being extended or while an access taxiway is being constructed. The amount of taxi traffic in these operations in terms of coverages is rarely significant in the total pavement life picture, but such traffic would tend to produce a nonuniform settlement similar to that which developed at Columbus. If this differential settlement did develop on an active runway, it would represent a definite operational hazard to B–52 aircraft.

Chart 5: Here we have plotted settlement against coverages, and,



COLUMBUS AFB PROOF TEST SECTION
SETTLEMENT CURVE FOR
STATION 84 + 75

as a secondary scale, against projected years of service at the location of maximum settlement in the test lane. We can see that well over half the total settlement has occurred at 1,000 coverages or within the first 4 years of service. I would also point out that the settlement at Columbus was definitely caused by a densifying or compression of the flexible pavement materials below the asphaltic concrete, not by movement or shoving of materials. In fact, these materials in this denser condition may well be stronger than they were immediately after construction. In this connection we strive, with the construction equipment currently available, to produce in either roads or airfields as much density in our materials during construction as they may be expected to receive under actual traffic loadings. With aircraft growing at the present rate, this is becoming increasingly difficult to accomplish. We easily require 20 times as much compactive effort in constructing a heavy-load airfield pavement as is required on our highest type highway pavements.


℄ RUNWAY
LONGITUDINAL JOINTS
TRANSVERSE JOINTS
PLAN
CRACKS IN RIGID AND FLEXIBLE PAVEMENT AREAS
RIGID PAVEMENT
TRANSITION SECTION
FLEXIBLE PAVEMENT
ASPHALTIC CONCRETE
BURIED PCC SLAB
LONGITUDINAL PAVEMENT SECTION
RIGID PAVEMENT
TRANSITION SECTION
FLEXIBLE PAVEMENT
A
B
INCHES ABOVE BENCH MARK
6
5
4
3
2
1
0
LONGITUDINAL SURFACE PROFILES

My last chart, No. 6, shows at the top a diagram of the cracking that occurred in both the rigid and flexible sections during the traffic tests. The cracking in both the rigid and flexible pavements within the test lane was minor or hairline in nature. Cracking of this type would be expected after 20 years of service and is not detrimental. The cracking in the Portland cement concrete, outside the traffic lane, was caused by the settlement that occurred within the traffic lane, thus producing a tension in the top surface of the adjacent lane. This type of cracking would not be expected if the full B–52 traffic distribution pattern had been used.

The cracks in the flexible pavement averaged about one-quarter inch in depth and reached a maximum depth of 1 inch. The pavement was still waterproof at the end of the test.

The second diagram is a repeat on the pavement sections to keep us oriented. Again we see the 18-inch rigid pavement, the transition section, and the flexible section.

The top black line in the lower diagram (marked "Design Slope (0.1%)") shows the design slope along the center of the test lane. The darkly shaded irregular line (marked "As constructed area") shows the as-built pavement surface. The vertical distance between these two lines represents to true scale in inches the degree to which we conformed to design grade. When we consider that current criteria permits as much as ½-inch departure plus or minus from the design slope, we must conclude the as-built surface is well within the required grade tolerance.

The lower irregular line (shown in light shade) shows the final surface of the flexible pavement following the application of the test traffic. The vertical distance from this line to the upper irregular darkly shaded (as constructed) line shows the total settlement that occurred during the tests. The settlement reached a maximum of 1½ inches at point A and a minimum of 1 inch at point B. The final surface (lower irregular line), after the equivalent of 20 years of traffic, exceeds the ½-inch allowable departure from the design slope shown in the top black line. However, if we transpose the design slope downward a uniform 1¼ inches to the lower black straight line (marked "Adjusted Slope" (0.1%)), we see that the final surface is still within one-quarter inch of the adjusted slope.

A second part of our specification, in addition to the grade control, is the requirement that immediately following construction and for overall smoothness the surface shall not depart more than one-eighth inch from a 12-foot straightedge placed in a longitudinal direction nor more than three-sixteenths inch from the same length straightedge placed in a transverse direction. The surface of the "as-built" flexible pavements in the test lane at Columbus met both of these requirements. At the completion of testing, the final surface of the flexible pavement within the test lane still met the straightedge requirements in the longitudinal direction except in this area adjacent to the transition. In the transverse direction the surface exceeds the allowable departure from a 12-foot straightedge by about one-quarter inch.

Based upon the fact that the surface of the flexible pavement from the transition to the end of the test lane departs from the original construction requirements to only a minor degree after an equivalent of 20 years of traffic loading, we are satisfied that the pavement has performed satisfactorily for normal B–52 landing and takeoff traffic.

With regard to this short reach immediately adjacent to the transition, the longitudinal straightedge test shows a deviation of some five-eighths inch. Such roughness would be unsatisfactory. We build the buried slab to effect a smooth transition that should conform to the dotted line. We believe an improved transition can be constructed but, on the other hand, remedial construction that would bring this pavement surface back up to the dotted line is a very minor maintenance problem that could be corrected easily within 1 day and for about $1,000 at both ends of an actual runway.

I will summarize this portion of our presentation by repeating the conclusions previously given by General Wilson, which were based on the considerations that I have just discussed:

1. Considering normal B–52 operations only, we have concluded that the tests at Columbus Air Force Base demonstrated the validity of the design and construction procedures developed by the Corps of Engineers for heavy-load flexible runway interior pavements.

2. Runway pavements must, however, be capable of supporting incidental periods of B–52 taxi operation in addition to the normal landing and takeoff traffic. The tests indicated that objectionable differential settlement could possibly develop on runways where taxi operations are extended over a period of 6 months or longer.

3. The flexible-pavement surface in the immediate vicinity of the buried-slab transition between the flexible and rigid pavement sections developed a 5/8-inch depression across the width of the traffic test lane.

4. An average 1¼-inch subsidence of the flexible pavement in the traffic lane, combined with a peculiarity of the test traffic pattern, resulted in excessive differential settlement between the trafficked area and the nontrafficked area to either side. The abrupt change in surface elevation would not be expected under normal B–52 operations but would be a possibility under extended taxi operations.

5. The surface smoothness within the traffic lane itself after completion of the test complied essentially with the smoothness tolerance allowed during construction.

6. The Corps of Engineers feels that the pavements were designed and constructed under as representative conditions as possible, considering the unusually large number of sidewalk superintendents from both Government and industry.

7. The test was not intended to show an economic comparison between rigid and flexible pavement. Any such comparison based upon experience at Columbus Air Force Base would have little worldwide application. Local conditions will determine the economics.

8. The test was conceived and planned to establish the capability of flexible runway interior pavements only. The Corps of Engineers has not altered its position that primary taxiways and runways ends on heavy-load airfields should be constructed of rigid pavement except in exceptional geographic areas.

9. The Corps of Engineers has concluded that it is possible to construct heavy-load flexible runway interior pavement that will provide adequate service for normal B–52 operations. However, B–52 operational conditions may occur that could cause objectionable roughness in flexible pavement because of differential settlement. Therefore, as a general policy, we are in agreement with the Air Force that a center strip of rigid pavement in runway interiors is good insurance.

That completes my portion of the presentation, Mr. Chairman.

Mr. HÉBERT. Thank you very much, General. General, prior to the conduct of the test, did the Air Force and the Corps of Engineers come into agreement on the ground rules?

General WILSON. Yes, sir.

Mr. HÉBERT. They were in full accord? The Air Force agreed that the test was a fair test?

General WILSON. Yes, sir.

Mr. HÉBERT. As established by the Corps of Engineers?

(General Wilson nods.)

Mr. HÉBERT. So there is no dispute there?

General WILSON. No, sir; no dispute.

Mr. HÉBERT. General Brown has stated that it was not conducted in the area on the basis of economics. But now, placing the two alongside, the asphalt is cheaper than the rigid pavement, the concrete pavement?

General WILSON. In many areas. As I stated, and we will always state, the local conditions determine that. There are some areas in the country and in the world where rigid would always be cheaper than asphalt, but, generally speaking, asphalt will be cheaper than the rigid.

Mr. HÉBERT. There are some areas where the rigid pavement would be cheaper?

General WILSON. Yes, sir.

Mr. HÉBERT. For instance, what areas do you have in mind?

General WILSON. Well, we find that competitively in several parts of the country, Mr. Hébert, where, because of distances of haul of acceptable materials, or the availability of the concrete materials close at hand, availability of the mills, the cement, and so on, the availability of the types of construction equipment to the contractors that are bidding on the job. Sometimes the rigid will come out cheaper than the asphalt.

Mr. HÉBERT. Well, would it be a fair summation to say they are competitive?

General WILSON. They are competitive. Let us put it this way: The concrete or rigid is competitive, or a little more than competitive, in less areas than the flexible is.

Mr. HÉBERT. But they are competitive?

General WILSON. Yes, sir.

Mr. HÉBERT. So, projecting the test to an economic conclusion, you then would say that it is competitive, and in one area concrete would be cheaper and in another area asphalt would be cheaper?

General WILSON. My point is that, more normally, the asphalt would be more economical.

Mr. HÉBERT. More economical. Now, there is one important fact, too. Are the both equally safe, from the safety factor?

General WILSON. Well, that is the point we were trying to make, Mr. Chairman; that we agree with the Air Force that for the insurance in that safety, that the further down—as far as I am concerned, the further down the runway you go with the rigid the more certain you are of true safety. Because it is possible, and it does happen, that at certain places, because of the requirement for a repair program or some other operational reason, they actually use the center portion of the runway

as a taxiway for a period of time. We believe the test demonstrates that if you do that for a long period of time, relatively long, then you could develop differential ridges or settlement which would be unsafe in a flexible pavement.

Mr. HÉBERT. Do I understand you to say, then, that, actually, the rigid pavement is safer than the asphalt?

General WILSON. Rigid pavement we are more certain of being able to guarantee 20 years, with no serious differential settlement. However, for the normal type of operation, where you don't have to use the runway as a taxiway, which shouldn't happen on every field, we feel that the interior portion of the runways can safely be built with flexible pavement.

Mr. HÉBERT. Now, this test at Columbus was an actual physical test?

General WILSON. Yes, sir.

Mr. HÉBERT. And the only projection that you have on a theoretical basis is the element of the weather over a 20-year period? You projected that?

General WILSON. Well, that is true.

Mr. HÉBERT. From your data?

General WILSON. Yes, sir.

Mr. HÉBERT. From engineering data you have projected that and accepted your engineers' conclusions on that?

General WILSON. Right.

Mr. HÉBERT. Every other test, that is, every other feature of the test, the factor in the test, was an actual physical test?

General WILSON. Yes, sir. The one, it isn't irregularity but lack of practicality, let us say, which General Brown attempted to bring out was that to save money and time we tested one 14-foot width, rather than taking that bell curve and starting in the center with 5,000 coverages and working out to the 35-foot point on either side, down to zero coverages. That would have been more practical and would then have demonstrated whether or not we are correct in saying that we don't expect the differential settlement to be developed in a normal runway operation.

As the chart showed, there was a definite differential settlement on either side of this test lane. Now, in effect, what we are saying is that if we would have run the traffic over the full width of what we expect the airplane to cover, that would have ironed itself out and there would have been no detrimental. So we are projecting from the Corps of Engineers' viewpoint to that extent.

Mr. HÉBERT. And the Corps of Engineers is positive and definite that the test was a success and it did prove that you could put asphalt paving, which would sustain the load of the air traffic?

General WILSON. The normal type of operation; yes, sir.

Mr. HÉBERT. Normal type of aircraft operation. Did the Air Force comment to you after the test?

General WILSON. They are going to make a statement.

Mr. HÉBERT. I know they are going to make a statement. We will ask them that. But I want to ask you what they told you, so we will be sure to have both statements.

General WILSON. Yes, sir; we have gotten together on our statements. We have discussed them. We have reached as close a conclu-

sion as we can. I have tried to state our position here. And if theirs varies any from it, it is because we haven't gotten any closer. But we are generally together on the results which we have given here.

Mr. HÉBERT. Mr. Hess?

Mr. HESS. General, I take it from your statement and the questioning from Mr. Hébert here that where cost is not involved, where the rigid and the flexible might be equal in cost, that you would recommend a rigid construction?

General WILSON. For the center portion of that.

Mr. HESS. No. I am saying now for the entire field?

General WILSON. Yes, sir; I agree.

Mr. HESS. Then as a matter of insurance, in those fields that are built where the runway must be used as a taxiway, you would then recommend that the center strip be constructed of rigid and the—where there is a differential in price, now, you understand?

General WILSON. Yes, sir.

Mr. HESS. And the balance, then, be constructed of a nonrigid?

General WILSON. Yes, sir.

Mr. HESS. That is all.

General WILSON. My only exception to that is that there are areas in the world in which because of weather conditions I don't believe it is practical to construct rigid. For instance, at Thule, where the cost of putting in rigid pavement and heating your operation while you are doing it—in other words, the temperature range is such that you don't have enough above freezing time to build a big runway. That is why we make a statement in here that there are exceptional geographical areas.

Mr. HESS. Why would you say that all of the runways in Spain are built of nonrigid?

General WILSON. Why would I say that, sir?

Mr. HESS. Have you any idea? There are concrete on the ends, but the center portion is not. I was over there 2 weeks ago.

General WILSON. I still say that you have an excellent chance of successful operation even with an all flexible runway, if conditions require you to put that in. However, you are safer and surer with your channelized traffic where you use the rigid pavement.

Mr. HESS. That is all, Mr. Chairman.

Mr. HÉBERT. Mr. Cunningham?

Mr. CUNNINGHAM. No questions.

Mr. HÉBERT. Mr. Bates?

Mr. BATES. General, if you build this center strip, won't you have the same problem on the side of that as you do with the slab today?

General WILSON. I don't believe so. I did think so the last time we were testifying to you, but—I will put it this way: I believe that the more experience we get in observing how they operate these B–52's, that they do follow for a long way down that runway when they are taking off that paved centerline on that runway. Hence, the time—if you make your concrete center strip 75 or greater feet wide it will be a rare occasion when the heavy wheels of that airplane actually get off on to the 2 sides.

Mr. BATES. You have a pretty good frequency distribution on that chart there, just on the left.

General WILSON. Yes, sir. But you will notice—if you add those 2 together and you get 75 feet. We are talking about a 75-foot minimum width of rigid.

Mr. BATES. I see.

General WILSON. Now, you do still have airplanes that for one reason or another have to wander beyond that. But there is no question at all in my mind that the flexible pavement will carry a reasonable amount of that type of operation.

Mr. BATES. Then you don't think you will have that problem?

General WILSON. No, sir.

Mr. BATES. Now, have you projected your thinking to later planes than the B–52, as far as load is concerned?

General WILSON. Well, we have officially and informally, and in every other way, asked the Air Force to give us a requirement if the loads are going to increase, and they repeatedly assure us that this is it.

Mr. BATES. That is for 20 years?

General WILSON. Well, you are asking the same question I have been asking, Mr. Bates.

Mr. BATES. That is what we are talking about.

General WILSON. Yes, sir.

Mr. BATES. We are talking about a 20-year proposition.

General WILSON. I am talking into the future, as far as can be seen. We have asked if there will be greater loads, with the relative tire pressure. In other words, whether we should not be trying to develop better information to design for an even more severe condition. And we have gotten the answer back in writing that, no, this is it.

Mr. BATES. When are you going to use these runways for taxiways? When work is being done on one? Under what conditions are you going to use it for taxiways?

General WILSON. Well, let's say you determine at a later date that you need an extension on the end of a runway.

Mr. BATES. Yes.

General WILSON. At the time that you were extending, let's say, the right-hand end of that runway you could still conduct operations from the remainder of the runway by just putting—that is, by using that cross-taxiway right there, or you might have to come in on this next one, right there, Mr. Sale. Go on to the runway and taxi to the right, to get into a takeoff position.

Mr. BATES. I see. Well, that is something after the strip has already been built?

General WILSON. Yes, sir; after it has been built.

Mr. BATES. But your decision on a new runway will have to be made at the time that the new strip is made.

General WILSON. Right.

Mr. BATES. How are you going to project your thinking as to the possibilities for the future? Are you going to have taxiways which will take care of these emergencies, or are you going to go ahead and say, "Well, if we run into trouble, maybe we will have to project this, therefore, we are going to have this center strip"? Just how are you going to proceed from this particular study now? That is why I don't quite clearly understand.

General WILSON. Well, in the first place, Mr. Bates, we are going to have to build what the Air Force tells us to.

Mr. BATES. I understand.

General WILSON. They have the duty and the right to evaluate all this, and to evaluate it against their safety requirements, and the cost of the airplane, and so on, and if they tell us to put the center strip in with rigid, that is what we will do.

Mr. BATES. I understand that. But now from your own experience, how do you think this thing would proceed, from your background?

General WILSON. I am certain from my own background that it will be somewhat affected by economics, that if the rigid is not particularly more expensive in a particular location, that we will probably put in the rigid center strip. But if it were considerably more, I think we would probably end up by saying, "Well, we will trust that we don't have to use this for a taxiway for an excessive period of time," and put it in in flexible and probably it will hold up pretty well.

Mr. BATES. It is going to be anybody's guess as to whether or not it will be needed for taxiways? Or would that be part of the design?

General WILSON. The determination would have to be made in advance, and then there would have to be design.

Mr. BATES. That is all.

Mr. HÉBERT. Mr. Osmers.

Mr. OSMERS. Mr. Chairman.

No one has mentioned what might happen in the event of combat. Supposing an airfield is under attack with the type of World War II bombing attack that airfields were subjected to. Do you have any thoughts there, General, as to which type of airstrip we would more quickly get back into use in actual combat, rather than in some ideal place in Mississippi?

General WILSON. In the terms of your question, utilizing World War II weapons, I don't have any doubt that we can repair a flexible pavement more rapidly that we can repair a rigid pavement.

Mr. OSMERS. What type of repair facilities are available at the average Air Force base from which these B–52's would depart? Do we have facilities to repair the type of pavement that exists there?

General WILSON. Well, I would prefer you to ask that question of the Air Force representatives. But, generally speaking, they take care of routine maintenance right now, and if they——

Mr. OSMERS. No; I don't mean routine maintenance. I am referring now to bomb holes.

General WILSON. If we are talking in the United States, I think that we will be utilizing the construction industry to back us up in the event of that type. If we are talking overseas, I think it will be troop repair, basically heavy construction engineer units. They will be capable of doing either type.

However, again I repeat, they will be able to do it more rapidly in repairing a flexible.

Mr. OSMERS. Well, obviously, it wouldn't be require much of a bomb to put one of these runways out of business. And all I am trying to do is to apply all of this data done under ideal conditions, and in a very peaceful part of the United States, to the purpose for which this is

all being done, namely, combat. Now, under actual combat conditions overseas at an average base, what happens if one of these runways gets bombed? Now, at home we put it out to contract, as I understand, with any road contractor who happens to be in the area. But we are overseas now. What happens? We are on an island; what do we do?

General WILSON. In wartime, even in the United States, we have an arrangement with the construction industry that would let them get in much faster than putting it out for advertising.

Mr. OSMERS. About the second year of the war, probably; yes.

General WILSON. I have discussed this point with our people, and with Air Force people—not necessarily here to prepare for this, but from my own background in various parts of the world. And one very logical answer I always get from the people in the Air Force, who have thought about it, is this: Sure, if we are under the gun we are going to take these airplanes off under less safe conditions. But why should we risk the amount of money tied up in one of these aircraft on a daily basis just because we may have to take them off under adverse conditions at some time in the future.

Mr. OSMERS. I certainly agree with that statement as a matter of principle. I am still thinking of some place, say, like Okinawa. You have a hole in the pavement, and you can't take them off and you can't land them. Now, what are you going to do?

General WILSON. Well, we are going to have to go in there fast and just patch the hole by the quickest means to let them get the immediate operation out of the way, and then close her down for a short period of time and try to make a semipermanent repair. Even in the rigid portions of the runway, I presume that if flexible is the quickest way to patch it, that is what we will do.

Mr. OSMERS. Well, we would if we had the material and the equipment to do the patching there.

General WILSON. Sir, I can't answer positively as to their ability to do it immediately in the event of a war, because I am not that certain of how much equipment and personnel they have on hand at each base.

Mr. OSMERS. Well, just in general terms, how long before you made a patch with flexible material would you be able to use it, even with some hazard?

General WILSON. How soon after?

Mr. OSMERS. Yes, put it down and roll it, how soon afterward?

General WILSON. Well, if the condition is serious, almost in a matter of an hour.

Mr. OSMERS. All right. And in the case of a rigid pavement how soon before you could use it after you poured it?

General WILSON. If it was a serious condition, I would say 24 hours.

Mr. OSMERS. Thank you.

Now, there is one other field that you touched on very briefly, and that is the subject of temperature.

General WILSON. Yes, sir.

Mr. OSMERS. Now, you said in some places you just can't get the rigid pavement as a practical matter. I think you used Thule as an example.

General WILSON. I used Thule primarily; yes, sir.

Mr. OSMERS. Now, all of these tests were conducted in an area where the temperature is rather constant; isn't that so?

General WILSON. Well, not quite, sir. We deliberately picked a time when we had particularly hot temperatures, because those are more difficult for the flexible pavement. In other words, the test was set up in such a manner that a certain percentage of the days would be above I think it was 90° temperature, in which the rolling was being done. So it wasn't uniform. It did not get—it was not tested under freezing conditions.

Mr. OSMERS. Do you feel that with respect to temperature, that the tests were fair and were representative, and that we would not have gained anything particularly in knowledge if we had tested them under subfreezing conditions?

General WILSON. Yes, sir; I do. My point of putting the temperature in was in the process of construction. To put in a rigid pavement you should never place it, that is, place the concrete, below freezing. Therefore, you ought to heat it, and—put a tent up or do something in order to keep it from getting below freezing at the time you are placing and for some period of time in days subsequent thereto, to let it cure.

At Thule, for instance, that would mean that you would have a very short period, maybe a couple of months, in which you were pretty safe not to have to go to this extra expense. But a pretty short period.

You can place flexible pavement safely a longer period of time as far as the construction. As far as the use of it afterward, I wouldn't try to bring that into the picture, because I don't think that is the factor.

Mr. OSMERS. Mr. Chairman, there seems to be coming out of these replies some indication that, regardless of the type of pavement that you might have at a combat airfield, that those on hand had better be ready for patching and repair with flexible material if that is to remain maximum operational during combat conditions.

Am I getting a wrong impression, General?

General WILSON. You are not getting a wrong impression from me; no, sir. I agree with that.

Mr. OSMERS. Thank you. That is all I have to say.

Mr. HÉBERT. Mr. Lankford, do you have any questions?

Mr. LANKFORD. Thank you, Mr. Chairman.

General, have any tests been conducted as to the safety of the two surfaces, thinking about skidding and that sort of thing?

General WILSON. I am not knowledgable enough to give you an answer on that, sir. I don't know. We will have to ask the Air Force representatives when they come up. I don't believe that is a major issue, as far as the actual operation.

Mr. LANKFORD. Thank you.

Mr. HÉBERT. I think it is important. The position of the subcommittee since the day we first started these hearings under Mr. Hess some years ago. The committee has never been in a position to advocate one over the other, the asphalt over the other. The committee has only been interested in the competitive nature.

General WILSON. Yes.

Mr. HÉBERT. Of course, assuming that one is as good as the other. Then the committee, of course, is interested in the economics of it. I think that has been the position of the committee.

Mr. HESS. That is right.

Mr. HÉBERT. We have never advocated one over the other. Our only interest has been and our only concern has been the economics. I think that should be brought well in focus.

Mr. COURTNEY. I have some questions, Mr. Chairman.

Mr. HÉBERT. Mr. Courtney.

Mr. COURTNEY. General Wilson, or General Brown, whichever one of you chooses to answer these questions, just for clarification.

I have before me this technical report, No. 3–490, of November 1958, which was prepared and circulated by the corps. It is a document that was sent to all of these participants and people who indicated an interest.

Before I read from this, Mr. Chairman, I would like to have the report, Engineer Technical Report No. 3–490—that is the text—put into the record in full, with the exception, of course, of the exhibits. And I will now read from several portions.

Mr. HÉBERT. So ordered.

(Technical report No. 3–490, dated November 1958, is as follows:)

PREFACE

Authority for the conduct of an accelerated proof test of flexible pavement design for interior portions of runways, designed and constructed for B–52 use, was contained in a letter from Headquarters, United States Air Force, to the Office, Chief of Engineers, dated July 30, 1957. The Air Force requested that a portion of the runway which was then under construction at Columbus, Miss., be used for the test.

The runway at Columbus, Miss., was designed and constructed under the supervision of the Mobile district of the South Atlantic division with Mr. Laurin E. Crowder as Corps of Engineers resident engineer at Columbus Air Force Base. The traffic testing was performed by personnel of the Waterways Experiment Station, Vicksburg, Miss.

Personnel of the Waterways Experiment Station actively connected with the testing and performance observations of the proof-test section were Messrs. W. J. Turnbull, C. R. Foster, A. A. Maxwell, O. B. Ray, C. D. Burns, A. H. Joseph, L. M. Womack, J. C. Bunyard, H. B. Boyd, J. D. Garnett, D. M. Pennington, and L. L. Steen. This report was prepared by Messrs. Burns, Joseph, and Womack.

SUMMARY

A portion of the runway pavement at Columbus Air Force Base was subjected to 5,000 coverages of accelerated traffic with a test-load cart designed, loaded, and operated to simulate B–52 aircraft traffic. The traffic testing was performed during the period September 4–28, 1958. The test area subjected to traffic was about 250 feet long by 15 feet wide and consisted of 200 feet of flexible pavement and 50 feet of rigid pavement. The primary objective of the test was to proof-test the Army Corps of Engineers flexible pavement design and construction methods for interior of runways for B–52 traffic. It was desired that the test include the juncture between the rigid and flexible pavements. Therefore, the test section included 50 feet of rigid pavement. The traffic was applied in accordance with test procedures previously agreed to by representatives of the Air Force and the Corps of Engineers. The traffic resulted in some settlement and cracking in both the rigid and flexible pavements. The settlement averaged about 1¼ inches for the flexible pavement and about 0.4 inches for the rigid pavement. Intermittent cracks, parallel to the direction of traffic, developed at about 1,000 coverages in the asphaltic concrete. Throughout the remainder of traffic, the cracks sealed during hot periods and reopened during cold periods. The maximum depths of cracks were in the order of 1 inch. Cracking also occurred in the rigid pavement. The most severe crack in the rigid pavement was first noted at 1,107 coverages and was located about 6 feet outside of the traffic lane, running parallel with the traffic lane for a distance of 35 feet, then angling into the traffic lane. This crack opened slightly with a very light amount of spalling along the edges of the crack as traffic was continued to 5,000 coverages. The other cracks in the rigid pavement were of a minor nature.

PROOF-TEST SECTION, COLUMBUS AIR FORCE BASE

PART I. INTRODUCTION

1. Accelerated traffic tests were conducted on a portion of the runway pavements at Columbus Air Force Base, Miss., from September 4 to 28, 1958. The primary purpose of the tests was to proof test the Army Corps of Engineers flexible pavement design and construction methods for interior of runways for B–52 traffic. It was desired that the juncture between the flexible and rigid pavements be included in the tests. Therefore, in order to test the juncture, a portion of the rigid pavement was also subjected to traffic.

2. This report describes the runway pavements, test section, test conditions, and test results.

PART II. RUNWAY PAVEMENTS

SITE CONDITIONS

3. Columbus Air Force Base is located at Columbus, Miss., in the northeast portion of the State, in a temporate climate with long, warm summers and short, usually mild winters. The average annual temperature is 64°, with average monthly temperatures ranging from 46° in January to 82° in July. Extreme temperatures experienced have been a minimum of —7° and a maximum of 113°. The average annual rainfall of 53 inches is fairly evenly distributed throughout the year.

4. The terrain at the airfield site is divided into 2 terraces, with a difference in elevation of approximately 25 feet. The natural soil in the higher terrace is primarily sandy to clayey gravel, and that in the lower terrace is primarily fine-grained silty to sandy material. The southeastern part of the runway lies on the higher terrace, and construction operations were such that the runway in this area was in cut sections. The northwestern part of the runway lies on fill material. In the vicinity of the proof test, the fill is approximately 9 feet thick and is composed of sandy to clayey gravel taken from the upper terrace. Drainage in the area is normally good.

DESIGN

5. A layout of the runway is shown in plate 1. The runway is 12,000 feet long by 300 feet wide and consists of both rigid and flexible-type construction. The first 1,000 feet on each end of the runway, and the center 75 feet of runway extending for an additional 2,500 feet from each end are portland-cement concrete; the remainder of the runway is flexible-type pavement. In planning for the tests, it was agreed with the Air Force that the test section would be located within the central 75 feet of the runway at one or the other locations where the flexible and rigid pavements join. The specific location was to be selected by the Air Force after construction was completed. It was desired that these tests relate to the requirements for the B–52G aircraft which require pavements designed for a 265,000-pound gear load.

Since none of the pavements at Columbus was planned for this latest design load, the areas in the vicinity of the juncture of the flexible and rigid pavements were designed for a 265,000-pound gear load. Design procedures specify a reduction in load to compensate for partial uplift of the wings; the reduction in this specific case was 20 percent. The areas designed for the 265,000-pound gear load (reduced to compensate for partial uplift) were in the central 75 feet of the runway between 33+00 and 40+00 and between station 78+12.5 and 87+00. This provided 500 to 700 feet of flexible and 200 feet of rigid construction in each of the 2 areas designed for the intended test load.

CONSTRUCTION

6. The runway pavements in the 2 possible proof-test locations were constructed under 2 separate contracts. The runway grading was accomplished by Charles R. Shephard, Inc. The R. G. Foster Co. was prime contractor for the construction of pavements in these areas.

7. All the portland-cement concrete paving in the possible test-section areas was completed on November 11, 1957. The flexible pavement was completed in the two possible proof-test locations on August 25, 1958.

Part III. Proof-Test Section

LOCATION

8. At the completion of construction of the runway pavements in the 2 possible test locations, the United States Air Force selected an area between station 83+00 and 85+50 (plate 1) as the test location. The Air Force requested that the centerline of the traffic lane be located 18.75 feet southwest of the centerline of the runway.

DESCRIPTION

9. The test section is 250 feet long by 14 feet 4 inches wide and consists of 200 feet of flexible pavement and 50 feet of rigid pavement. As previously stated, the primary objective of the traffic test was to proof-test the flexible pavement design. However, since it was desired that the juncture between the rigid and flexible pavement also be tested, the proof-test section included 50 feet of the rigid pavement. Plate 2 shows a plan of the center 75 feet of runway and a layout of the traffic lane within the runway section. Sections A–A and B–B of plate 3 show a typical section of the rigid and flexible pavement, respectively; plate 4 shows a profile along the centerline of the traffic lane.

10. This portion of the runway was constructed on a fill, and the pavement surface is approximately 9 feet above the natural ground. The CBR and compaction requirements indicated in plate 4 are the design requirements for the flexible pavement construction. It is pointed out that the original design for the center 75 feet of runway between the 1,000-foot portland-cement concrete ends was all flexible pavement, and that the construction was accomplished up to within 10 inches of the surface elevation in accordance with the original design. At this time the design was changed to require that the rigid pavement extend out to 3,500 feet from the end of the runway. The clay-gravel subbase which had been constructed under the earlier contract was used directly for the foundation of the portland-cement concrete. The clay-gravel subbase and the underlying fill had been constructed under a specification which required higher densities than would normally be specified for a rigid pavement design. A description of the various materials is given in the following paragraphs.

Fill

11. The fill material was obtained from the southeast end of the runway which was in a cut section. The material consisted mostly of clayey gravel. The natural ground upon which the fill was placed was wet and relatively soft at the time of placement; therefore, the first layers of fill were placed in thick lifts (2 to 3 feet). As the height of the fill increased, the thickness of the layers was decreased and the compaction effort increased as necessary to obtain the minimum density required. For this report, the fill material is considered the subgrade for the pavements. The design density and CBR requirements are indicated on the profile in plate 4. The design k value for the fill was 250 pounds per inch^3 and this was applied to the determination of the thickness of portland-cement concrete pavement.

Clay-gravel subbase

12. The clay-gravel subbase was local pit-run material, about 1½ inches maximum size, with 10 to 25 percent passing a No. 200 sieve, and having a plasticity index ranging from 0 to 15. The design CBR value for this material was 20. The material was originally placed as a subbase (and the term was retained); however, when the pavement was redesigned the material was classed as select material. Specifications for select material contain no gradation requirement, but suggest that the maximum-size aggregate be 3 inches and plasticity index be less than 12. The clay-gravel subbase extends under both the rigid and flexible pavements, as shown on the profile in plate 4, and is 13 inches thick under the flexible pavement. The compaction requirement for the lower 6 inches of the clay gravel was 95 percent of modified AASHO maximum density and 100 percent for the upper 7 inches. In addition, the top of the clay-gravel subbase was subjected to 30 coverages of proof rolling with a 60-ton, 150 pounds per square inch, rubber-tired roller.

Sand-gravel subbase

13. The sand-gravel subbase consisted of three-fourth-inch maximum size crushed chert gravel, sand, and limestone dust blended to produce a fairly well graded material having a design CBR value of 40; it was placed in two lifts.

Crushed slag was blended with the lower lift. The graduation requirement was for 2-inch maximum-size material with not more than 50 percent passing a No. 10 sieve nor more than 15 percent passing a No. 200 sieve. The specified plasticity index was less than 5. The compaction requirements were 100 percent of modified AASHO maximum. In addition, the top layer of subbase was subjected to 30 coverages of proof rolling with a 60-ton, 150-pound-per-square-inch, rubber-tired roller. This material was used only under the flexible pavement section, as indicated by plate 4.

Crushed-aggregate base course

14. The crushed-aggregate base used in the flexible pavement section consisted of a blend of slag, crushed chert gravel, sand, and a small amount of limestone dust. This material was blended in a pugmill in proper proportions to meet the gradation requirements. The blended material was well graded and nonplastic. Grading curves of samples of the blended material are shown in plate 5. The design compaction requirement for the base was a minimum of 100 percent of modified AASHO maximum density prior to proof rolling. Each layer of the base course was to be subjected to 30 coverages of proof rolling with the 60-ton rubber-tired roller following the initial compaction. The design CBR value was 100. This material was used only under the flexible pavement section, as indicated by plate 4.

Asphaltic concrete

15. The asphaltic concrete consisted of a 2½-inch thickness of binder course and a 1½-inch thickness of surface course mix. The aggregates for the paving mixtures consisted of a 1-inch maximum-size crushed limestone, three-fourths-inch maximum-size crushed chert gravel, one-fourth-inch maximum-size limestone screenings, coarse washed sand, and fine bank sand.

16. A job-mix formula was prepared on plant-mixed, laboratory-compacted samples for both the binder and surface course mixes using the stockpile aggregates described above and an 85–100 penetration asphalt supplied by the Shell Oil Co., Norco Refinery, Baton Rouge, La. Test properties of the asphalt used are shown in table 1. The stockpile aggregates were combined in the following proportions:

Stockpile aggregate	Percent used	
	Binder course	Surface course
1-inch maximum limestone	24	----------
¾-inch maximum crushed chert gravel	34	46
¼-inch maximum limestone screenings	26	34
Course washed sand	9	12
Fine bank sand	7	8

17. The combined grading curves for the binder and surface course mixes, along with the gradation specification limits, are shown in plates 6 and 7, respectively. The design criteria for determining the satisfactoriness of the asphaltic concrete mixes at optimum asphalt content were as follows:

Test property	Surface course	Binder course
Stability (Marshall)	1,800 pounds or higher	1,800 pounds or higher.
Flow (Marshall)	16 or less	16 or less.
Percent voids total mix	3 to 5	5 to 7.
Percent voids filled with bitumen	70 to 80	50 to 70.

The mix design properties for the binder- and surface-course mixes are shown in plates 8 and 9, respectively. From these tests the normal optimum asphalt content for the 75-blow Marshall compaction effort was established as 4.4 percent for the binder course and 5.6 percent for the surface-course mix. During construction of surface and binder course at optimum, the specifications listed above were met. The runway design required a 20-percent reduction in asphalt content for the center 75 feet of the runway. Therefore, for this portion of the runway the asphalt content was reduced to 3.5 percent for the binder course

and 4.5 percent for the surface-course mix. All of the binder-course material for the center 75 feet of the runway was placed at an asphalt content of 3.5 percent. However, during placing of the surface-course mixture, there was a decrease in voids total mix, as indicated in plate 9, which was caused by a slight change in the properties of the aggregate. This required a slight adjustment in the optimum asphalt content. The actual asphalt content used in the surface-course mix of the proof-test section was 4.3 percent. Attention is directed to the fact that current practice for mixes placed at reduced asphalt contents calls for the mix to meet the specification requirements when prepared at optimum asphalt content. When the asphalt content is reduced, the test values (stability, voids, etc.) may not necessarily meet the specification requirements.

18. Marshall test properties of the plant-mixed, laboratory-compacted samples are shown on the top line of table 2. No difficulties were encountered in mixing or placing the material. The paving in the area of the proof-test section was completed on August 25, 1958.

Portland-cement concrete

19. The concrete aggregate consisted of local washed chert gravel and sand. The gradation of the coarse and fine aggregate is shown in plate 10. In the area of the test section, the blend contained 66 percent coarse aggregate and 34 percent fine aggregate. Cement factor was 5.5 sacks per yard, and water-cement ratio was 5 gallons per sack. The air content ranged from 3.1 to 3.6 percent, and the slump was 1.5 inches. The design flexural strength for the concrete was 700 pounds per square inch. This value, together with the design k value of the subgrade of 250 pounds per inch^3 required a pavement thickness of 18 inches in the interior with 22-inch thickened edges (sec. A–A of pl. 3).

20. The portland-cement concrete for the center 75 feet of the runway was placed in 25-foot-wide longitudinal lanes. The longitudinal construction joints are keyed (sec. A–A of pl. 3). The transverse contraction joints are sawed dummy-type joints spaced at 25-foot intervals. The southwest lane of portland-cement concrete, which was in the traffic-test lane, was placed on November 11, 1957. The center lane, west edge of which was also subjected to traffic, was placed on November 1, 1957.

Transition joint

21. A detail of the buried slab transition between the rigid and flexible pavements is shown on the profile in plate 4. The base material was originally placed and compacted to final grade all the way back to the portland-cement concrete juncture. The base was then cut out to a vertical face for a distance of 12 feet beyond the end of the portland-cement concrete pavement, and the concrete was placed against the face of the base course. The buried slab was placed transversely across the center 75 feet of the runway. The transverse joint was doweled, as indicated in plate 4. Longitudinal dummy joints were sawed in the slab to coincide with the longitudinal construction joints of the portland-cement concrete pavement. The buried slab was placed on July 29, 1958. The asphaltic concrete pavement was constructed over the buried slab, as indicated in plate 4.

Part IV. Traffic Testing and Test Results

TEST CONDITIONS AND PROCEDURES

22. The traffic tests were performed under conditions and procedures previously agreed to by representatives of the Air Force and the Corps of Engineers. These conditions are discussed in the following paragraphs.

Test cart

23. Traffic was applied to the test section with a test-load cart as shown in photograph 1. The test cart consisted of a load box, equipped with a twin-twin wheel assembly, which was towed by a Tournapull Super C tractor. The box was loaded to result in a net weight of 212,000 pounds on the 4 airplane-type wheels under the load box (photograph 2). This represents a 265,000-pound load for the aft gear assembly of a gear assembly of a B–52 aircraft (see pl. 11) reduced by 20 percent to compensate partially for the wing life that occurs on the runway. The tires are 56 by 16, 32-ply airplane tires mounted on axles with tire spacings as

shown in the gear layout, plate 11. The tires were inflated to 266 pounds per square inch, which was determined from the following formula being used by the Air Force.

$$\text{Inflation pressure} = \frac{\text{gross plane load}}{1000} \times 0.521 = \frac{510{,}000}{1000} \times 0.521 = 266 \text{ pounds per square inch}$$

Test lane

24. The traffic-test lane was 250 feet long, which included 200 feet of flexible pavement and 50 feet of rigid pavement. As previously stated, the location of the traffic lane was selected by the Air Force. From the layout shown in plate 2, it can be seen that the traffic lane includes 2 longitudinal joints in the surface course of the flexible pavement and 1 longitudinal construction joint and 1 transverse contraction joint in the rigid pavement.

Traffic pattern

25. The test-load cart was operated back and forth in the traffic lane and was shifted laterally on each forward pass to obtain uniform coverages of traffic over the 14-feet-4-inches-wide traffic lane. A coverage is defined as a single-wheel-load application over all points in a given area. The load cart was operated at a speed of about 4 miles per hour. The pattern followed in applying the traffic is shown in plate 12. From this pattern it can be seen that in applying uniform coverages over the 14-feet-4-inches-wide traffic lane 1 wheel of the assembly ran in the area 1 to 2 feet outside the traffic lane, but a blank space about 1 foot wide on each edge of the traffic lane received no traffic. This width lane and traffic pattern were chosen for reasons of economy. After about 400 coverages of traffic, it was noted that settlement had occurred in the traffic lane and in the area outside the traffic lane where the outside wheel ran, which resulted in a ridge along the blank space which was receiving no traffic. Under normal operations of aircraft, traffic would be distributed over a wider area and not be concentrated in 14 feet; therefore, for the remainder of traffic, the cart was shifted occasionally to apply a small amount of traffic over this blank space, which resulted in nonuniform coverages of traffic over an area 2 to 4 feet wide on each side of the uniform-coverage traffic lane. The amount of traffic applied in the blank space was not sufficient to iron out the ridge and it continued to develop throughout the period of traffic. Shifting traffic for this area did not affect the uniformity of the application of traffic within the test lane.

Coverages and temperature

26. A total of 5,004 coverages of traffic was applied during the period September 4 through September 28, 1958. Table 3 is a daily log of traffic. The traffic was applied as nearly as practicable for 24 hours a day, 7 days per week, until the 5,000-coverage level was reached. Pavement temperature controlled the rate of application of traffic to some extent as it was required that the percentage of coverages versus temperature fall within 2 percentage points at 90° F. of a predetermined pavement-temperature distribution curve. Curve 1 of plate 13 shows the pavement-temperature distribution curve obtained at Vicksburg, Miss., for the period June 1, 1957, through May 1958. It was agreed with the Air Force that this curve would be used to control traffic. Curve 2 of plate 13 shows the actual traffic distribution with pavement temperature at Columbus, Miss. The pavement temperature was that measured at the surface of the pavement. As can be noted from plate 13, the traffic was applied over a range of pavement temperatures from 65° to slightly above 130° F. The hot-weather traffic (above 90° F.) agrees very closely with the 1-year temperature-distribution curve However, the below 90° F. pavement temperature traffic was applied at temperatures of from 65° to 90° F. as compared to 20° to 90° F. for the annual curve. About 10 percent of the traffic coverages were applied during light rain or on wet pavement. The night traffic was performed under floodlights. A general view of the night traffic operations is shown in photograph 3.

BEHAVIOR UNDER TRAFFIC

27. Visual observations of pavement behavior were recorded at various coverage intervals during traffic. These observations were supplemented by (1) level readings to establish the settlement [permanent downward movement], (2) deflection measurements [downward movement under a given load application which in this case is practically equal to the elastic deflection], (3) Marshall test properties determined from cores cut from the asphaltic concrete, and (4) photo-

graphs. Cracking that occurred during traffic is summarized in table 3. The various data obtained during the traffic test are presented in the following paragraphs:

Pavement-core data

28. Marshall test properties obtained in tests on cores samples cut from the asphaltic concrete at various intervals of traffic are summarized in table 2. These data show that the initial density of both the surface and binder course mixes was 98 percent of the laboratory design density [zero coverage data]. The voids total mix corresponding to 98 percent density were 8.3 and 10.7 percent for the surface course and binder courses, respectively. The stability values at zero coverages were 537 and 1,410 for the surface and binder courses, respectively. As traffic was applied, an increase in pavement density and a decrease in voids total mix occurred for the first 1,100 coverages, with very little change in density or voids thereafter. The stability of the pavement showed a continuous increase throughout the period of traffic.

29. The rate of densification of the asphaltic concrete is best illustrated by a plot of voids versus coverages as shown in plate 14. From these data it can be seen that a rapid decrease in voids occurred during the first 200 coverages of traffic, gradually decreasing up to about 1,000 coverages, with very little change occurring beyond 1,000 coverages. At the end of traffic the voids total mix were 5 percent in the surface course and 8.4 percent in the binder course. These data, along with visual observations, show that the asphaltic concrete [both surface and binder courses] had sufficient strength and was sufficiently resistant to compaction to withstand the traffic in these tests without flushing or excessive reduction in voids.

Pavement deflection

30. Surface-deflection measurements were made at two locations on both the flexible and rigid pavement at zero coverages and at various intervals during traffic. The term "deflection" as used in this report indicates the total downward movement that occurs with a single-load application. These measurements were obtained with a level instrument by reading rods [engineer scales] placed in a prearranged position on the pavement adjacent to and between the load wheels. The roads were read with the load on the pavement; then the load cart was moved forward, and a second reading taken with the load off. The difference in rod readings indicates the rebound of the pavement and, for practical purposes [checked in previous tests at WES with buried electronic deflection gages], the total downward movement of the pavement.

31. The deflection data obtained are shown in table 4. The schematic diagram at the right indicates the locations where the readings were taken. The deflections in inches, corresponding to each of the deflection points, are listed on the left side of table 4. These data show that the maximum deflection of the flexible pavement under load was about constant throughout the period of traffic and was in the order of 0.08 to 0.1 inch. The pavement deflections did not increase with coverages and even showed a slight decrease at 5,000 coverages as compared to the value at 3,500 coverages. This is evidence that the strength of the material under the asphaltic concrete increased with traffic. The deflection of the rigid pavement was in the order of 0.07 inch near the juncture with the flexible construction and 0.05 inch at the other location tested.

Settlement

32. Level readings were taken prior to traffic and at various intervals of traffic across the test lane at 25-foot sections on the flexible pavement and at 1 location on the rigid pavement. Similar readings were taken along the center line of the traffic lane. These observations were made to determine the rate and magnitude of settlement.

33. Plate 15 shows typical sections across the flexible pavement. The section at station 83+50 represents about the minimum settlement on the traffic lane. Station 84+25 represents the average settlement and the section at station 84+75 indicates the maximum settlement. The settlement at station 84+75 averages about 1½ inches. These data show that the settlement in the traffic lane where uniform coverages of traffic were applied is quite uniform. The average of all settlement readings at the end of 5,000 coverages was approximately 1¼ inches. This settlement was primarily the result of densification of the underlying material since no shear failure occurred as evidenced by the small and diminishing deflections under traffic. The grooves just inside the

traffic lane are in the two longitudinal construction joints. As indicated by the zero-coverage cross-sections, these joints were low at the start of traffic and in some areas during traffic tended to settle a slightly greater amount than the rest of the pavement. The ridges noted just outside the traffic lane [at a coverage level of 411 and greater] are at the blank spaces indicated on the traffic pattern (pl. 12) where only a small amount of traffic was applied.

34. Cross-sections across the portland-cement concrete are shown in plate 16. The data for figure 1 were obtained on the portland-cement concrete 6 inches from the buried-slab juncture. The data for figure 2 were obtained at station 85+30, which was 5 feet from the sawed contraction joint at the end of 5,000 coverages of traffic. Level readings were not obtained at station 85+30 prior to traffic. These data show that the settlement in the portland-cement concrete pavement at station 85+0.5 averaged about 0.4 inch with a maximum of about 0.5 inch.

35. Level readings were taken at selected locations on both the flexible and rigid pavements at more frequent intervals than those made for the cross sections to establish the rate of settlement. Data are shown in plate 17 for four locations on the flexible pavement section. These data are plotted to logarithmic scale and result generally in a straight-line relation of coverages versus settlement. A similar plot of coverages versus settlement for station 84+25 plotted to an arithmetic scale is shown in plate 18. From these data it can be seen that most of the settlement occurred within the first 1,000 coverages. Similar data are shown in plate 19 for a location on the rigid pavement.

36. A plan and surface profile of the test section are shown in plate 20. The profile shows the initial and final centerline grade of the test section. The initial profile was obtained on the flexible pavement at 25-foot intervals along the centerline of the runway and at one point on the rigid pavement at station 85+00.5. However, by 411 coverages it was noted that considerable settlement had occurred in the flexible pavement and that settlement was occurring in the rigid pavement at station 85+00.5. Therefore, at the end of 411 coverages, level readings were taken at 1- to 5-foot intervals along the centerline of the traffic lane on the rigid pavement from station 85+00.5 to 85+25. These readings were used to establish the profile shown at 411 coverages.

The final profile at the end of 5,000 coverages was established from level readings taken at 1-foot intervals along the entire length of the traffic lane. The settlement along the centerline of the traffic lane is of the same order of magnitude as the values indicated from the cross sections measured at 25-foot intervals (par. 33, 34). The settlement was uniform so that the surfaces of both the flexible and rigid pavement were relatively smooth at the end of traffic; however, a differential settlement of one-quarter inch developed at the juncture between the rigid pavement and the asphaltic concrete. Also, a differential settlement of 0.6 inch developed at the end of the buried slab. (See also par. 40 through 43 for smoothness measurements.)

37. Views of the test section at various stages of traffic are shown in photographs 4 through 10.

Pavement cracking

38. Some cracking occurred in both the flexible and rigid pavements. The first cracking noted in the asphaltic concrete was at about 1,000 coverages when intermittent, hairline cracks developed parallel to the direction of traffic near the centerline of the traffic lane and along the two construction joints as indicated in the plan at the top of plate 20. Throughout the remainder of traffic these cracks ended to seal over during periods of hot weather traffic and reopen during periods of cool weather traffic. Photograph 5 shows the surface texture of the asphaltic concrete at 3,334 coverages and photograph 6 shows one of the cracks in the flexible pavement.

Examination of pavement cores cut through one of the most pronounced cracks at the end of 5,000 coverages indicated that the maximum depth of the cracks was in the order of 1 inch. A transverse crack developed in the asphaltic concrete at the end of the buried slab at about 2,800 coverages. This crack was visible throughout the remainder of traffic. In addition to these cracks, very fine hairline cracking occurred generally over the traffic lane at about 3,600 coverages. These cracks could be seen only as the pavement dried out after a rain when the cracks retained moisture. The depth of the cracks was so shallow that it could not be determined.

39. A number of small cracks occurred in all four slabs of the rigid pavements that were subjected to traffic (plate 20). The most severe crack that occurred was first noted at 1,107 coverages and was located about 6 feet outside the traffic lane, running parallel with the traffic lane for a distance of 35 feet, then angling into the traffic lane and terminating at the longitudinal construction joint and later extending across the joint as shown in plate 20. This crack opened slightly with a very light amount of raveling along the edges of the crack as traffic was continued to 5,000 coverages. This was the only crack that developed that could be detected to be working during traffic. Photograph 7 shows a portion of this crack at the completion of 3,334 coverages. A few other fine hairline, nonworking cracks were first observed at the coverages levels noted in plate 20, and at the completion of the 5,000 coverages the cracks were visible, with no spalling along their edges. When these cracks were first noted, they were from a few inches to 1 to 2 feet in length and progressed to the extent shown in plate 20 at the end of traffic. In some instances, the cracks were visible only as the pavement dried out after having been wet.

Smoothness tests

40. The Waterways Experiment Station requested the resident engineer at Columbus Air Force Base to make tests on the section to determine deviation of the surface from the construction tolerances for smoothness after completion of 5,000 coverages. The construction tolerances for surface smoothness are one-eighth inch in 12 feet in the longitudinal direction and three-sixteenths inch in the transverse direction. The tests were made on October 3, 1958, and were located within the limits of the uniform-coverage trafficked area. The results are given below.

41. Flexible pavement. After 5,000 coverages, the surface of the flexible pavement conformed to the construction tolerances in a longitudinal direction except at the juncture between the rigid pavement and the asphaltic concrete and at the end of the buried slab (station 84+87).

42. In the transverse direction, the surface of the flexible pavement conformed to the construction tolerances except at the two longitudinal joints in the surface course which are just inside the traffic lane made at 10-foot intervals (tabulated below) show the deviation from the three-sixteenths-inch tolerance in the lower part of the grooves. The designations "right" and "left" refer to the groove on the right or left of the centerline of the traffic area when looking in the direction of increasing station numbers.

Station	Deviation, inch		Station	Deviation, inch	
	Right	Left		Right	Left
83+00	1/4	3/16	84+00	0	1/4
83+10	1/16	3/16	84+10	1/16	3/16
83+20	1/16	1/4	84+20	1/4	1/4
83+30	0	1/4	84+30	1/4	1/16
83+40	0	3/16	84+40	0	1/4
83+50	1/16	1/4	84+50	1/4	1/4
83+60	0	1/16	84+60	0	1/4
83+70	1/16	1/4	84+70	0	1/4
83+80	1/16	1/4	84+80	0	1/4
83+90	0	1/4	84+87	0	1/4

43. *Portland cement concrete.*—After 5,000 coverages, the surface of the Portland cement concrete pavement conformed to the construction tolerances for smoothness in both the longitudinal and transverse directions except for a one-eighth inch deviation in the middle of the slab at station 85+12.5, which was present at the start of traffic.

Part V. Summary of Findings, and Conclusions

44. The following findings and conclusions are based on the behavior of the pavements under 5,000 coverages of accelerated traffic with a test cart loaded to simulate B–52 runway loading.

FLEXIBLE PAVEMENT

Asphaltic mix

45. Construction of the lean-mix pavement placed in the test areas presented no significant problems (par. 18).

46. The asphaltic concrete (both surface and binder courses) had sufficient strength and was sufficiently resistant to compaction to withstand the traffic in these tests without flushing or excessive reduction of voids (pars. 28 and 29).

47. Intermittent cracks, parallel to the direction of traffic, developed at about 1,000 coverages along the centerline of the traffic lane and along the two construction joints at each edge of the traffic lane. Throughout the remainder of traffic the cracks sealed during hot periods and reopened during cold periods. Maximum depth of crack was in the order of 1 inch (par. 38).

48. A crack developed in the asphaltic concrete at the end of the buried slab at 2,800 coverages and remained visible throughout the remainder of traffic (par. 38).

49. Very fine hairline cracking occurred generally over the trafficked area at about 3,600 coverages. The cracks were so fine that they could be seen only when they retained moisture. The depth was so shallow that it could not be determined (par. 38).

Base, subbase, and subgrade

50. The materials below the asphaltic concrete were adequate from a strength standpoint to withstand more than 5,000 coverages of the accelerated traffic applied in these tests (par. 31).

51. Densification occurred in the flexible pavement to the extent that settlement developed in the traffic lane, averaging about 1¼ inches and reaching a maximum of 1½ inches. The major part of the densification occurred in the first 1,000 coverages (pars. 33 and 35).

52. The densification resulted in an overall increase in strength of the flexible pavement structure (par. 31).

Deflection

53. The maximum deflection of the flexible pavement was in the order of 0.1 inch. The deflection was practically constant throughout the majority of the traffic period with a slight tendency to decrease during the latter stages (par. 31).

Surface smoothness

54. Settlement in the traffic lane was quite uniform except at the juncture of the portland cement concrete slab with the flexible-type construction where a differential settlement of one-quarter inch occurred, and adjacent to the buried slab where a differential settlement of 0.6 inch occurred (par. 36).

55. The grooves and ridges along the outside edges of the traffic lane were the result of nonuniform traffic distribution. The grooves along the traffic lane on the inside of the lane were the result of slight deficiencies in the two construction joints at these points (par. 33).

56. At 5,000 coverages, the surface smoothness within the area where traffic was uniformly distributed was within the construction tolerances (one-eighth inch longitudinal, three-sixteenths inch transverse deviation in 12 feet), except at the juncture of the flexible and rigid construction and at the two construction joints at each edge of the traffic lane (pars. 36, 42, and 43).

RIGID PAVEMENT

Deflection

57. The deflection of the portland cement concrete pavement was in the order of 0.07 inch near the juncture of the flexible pavement and 0.05 inch at the other location measured (par. 31).

Slab behavior

58. Settlement occurred in the portland cement concrete pavement. Immediately adjacent to the buried slab transition (the only location where initial readings were made), the settlement averaged about 0.4 inch, reaching a maximum of 0.5 inch (par. 34).

59. Cracking occurred along the outside of the traffic lane at 1,100 coverages and inside the traffic lane at 1,600 coverages. Cracking continued to develop with traffic through 3,700 coverages (par. 39).

60. Surface smoothness of the portland cement concrete slab at the end of 5,000 coverages was within construction tolerances, except for one deviation which was presented at the start of traffic (par. 43).

Just for clarification, do I understand that the concrete slab which paralleled the test slab was——

General WILSON. It did not parallel, sir. It abutted it.

Mr. COURTNEY. Abutted the test slab?

General WILSON. Yes.

Mr. COURTNEY. Was that overrun in the course of this test?

General WILSON. Yes, sir.

Mr. COURTNEY. In the same fashion that the flexible was?

General WILSON. Would you look at that chart right there?

Mr. COURTNEY. Yes, sir; chart 2.

General WILSON. Fifty feet of the rigid as an extension of the same 14-foot-wide lane was trafficked by the same cart.

Mr. COURTNEY. In the same test?

General WILSON. Yes, sir.

General BROWN. May I interject something, Mr. Courtney?

All the maneuvering of the test cart was done on the rigid pavement. In other words, when the operator would shift from lane to lane or from track to track he would do that maneuvering on the rigid pavement.

Mr. COURTNEY. On the rigid pavement. So that in the number of coverages and the weights applied, the same surface conditions prevailed during this test on a portion of the concrete strip?

General WILSON. Essentially.

Mr. COURTNEY. As prevailed on the test trip?

General WILSON. Yes, sir.

Mr. COURTNEY. You were able to observe what happened on the concrete strip, I assume, even though you were not testing it specifically?

General WILSON. That is correct.

General BROWN. Yes, sir.

Mr. COURTNEY. General, a question.

On page 4, your paragraph No. 10, without reading it in whole, I would like to have it put in the record. Would I understand from this, or does the record show that the subgrade structure under the rigid was the same as the subgrade structure under the flexible?

General WILSON. Let's get the chart out.

Mr. COURTNEY. That is your chart 3?

General WILSON. Yes, sir.

Mr. COURTNEY. I am speaking now of the area that was tested.

General WILSON. That is correct. That is all that shows on that chart.

Mr. COURTNEY. Then the answer to the question so far as the printed record is concerned is that the portion of the slabs, both rigid and concrete, had the same substructure?

General WILSON. Rigid and flexible.

Mr. COURTNEY. Had the same substructure; is that right?

General WILSON. No, sir; it is not quite right. You will have to go back and go through it on the chart. If you will look at the left side, you will see is shown the rigid pavement. You see that from the 18 inch down to the approximately 37 inch. Underneath that you

have the clay-gravel subbase, and from there on down you have that random sand gravel fill.

Now, that random is under both flexible and rigid. The clay-gravel subbase is under both. But you will notice that there is a difference in the depth.

Mr. COURTNEY. So far as the sand-gravel subbase is concerned, as it is identified on that chart, everything below that is equal.

General WILSON. Everything below the 25, approximately, inch point?

Mr. COURTNEY. Yes.

General WILSON. Point that out on the chart. Twenty-five inch point. In other words, level with that green line. Everything below that green line is the same.

Mr. COURTNEY. Is the same?

General WILSON. Yes, sir.

Mr. COURTNEY. And with the exception—I suppose it is a couple of inches; isn't it? What is it?

General WILSON. That is about 5, about 7 inches.

Mr. COURTNEY. The gray slab, called the burial slab, that projects into the sand-gravel subbase has a difference of how many inches or feet?

General WILSON. That is 1½ inches deeper than the rigid pavement. The buried slab projects 1½ inches further down than the normal rigid pavement.

Mr. COURTNEY. Than the normal rigid pavement.

Is the design of the rigid slab which you show on chart 3 the same design that you would employ for B–52 traffic?

General WILSON. Yes, sir.

Mr. COURTNEY. I am talking about the slab only now.

General WILSON. Slab only.

Mr. COURTNEY. In thickness and in mix?

General WILSON. And its design based on what we know is underneath it.

Mr. COURTNEY. Yes.

General WILSON. And if you had different conditions underneath it, you could have a different thickness.

Mr. COURTNEY. That is right. My question is this: Under the same conditions that you were testing the flexible pavement, would you have had the same substructure for a concrete slab?

General WILSON. Well, I am going to put it this way: The portland cement portion that was trafficked was designed to take the same loads as the flexible pavement that was trafficked, if that answers your question.

Mr. COURTNEY. Well, I understand that, but I am asking you if you were designing exclusively in concrete, portland cement, would you have had the same substructure that you employed here? Would it be of greater strength or lesser strength?

General WILSON. At the time that this particular section was put in we would have done the same—we would have used the same design that you see on the left-hand side of the chart, clear on across the chart, and has rigid pavement over the full length of it.

Mr. COURTNEY. Well, for what reason would you have done that?

General WILSON. Because that is what it would require.

Mr. COURTNEY. That would be required at this location?

General WILSON. And the conditions that existed.

Mr. COURTNEY. Right.

General WILSON. Because to get to the bottom of what you may be asking about, if you will remember, sir, this was about the third or fourth change in this particular portion of runway. Had we started from the very beginning to design a rigid pavement to carry these loads at this site, we would not have had exactly what we have here.

Mr. COURTNEY. All right.

Now, another question with reference to the printed record and the same report.

On page 11, paragraph 28, the last sentence states:

> The stability of the pavement showed a continuous increase throughout the period of traffic.

And following that, on page 12, paragraph 31, you state:

> This is evidence that the strength of the material under the asphaltic concrete increased with traffic.

Now then, I turn over to page 17, paragraph 50, and I find this conclusion:

> The materials below the asphaltic concrete were adequate from a strength standpoint to withstand more than the 5,000 coverages of the accelerated traffic applied in these tests.

And you refer back to paragraph 31 which is the one from which I have just read on page 12.

Now, my question is this: What significance does that have in the evaluation of this test by the subcommittee?

General WILSON. Instead of ending up after 20 years with the flexible pavement which was basically worn out because that was all it was designed for——

Mr. COURTNEY. Yes.

General WILSON. In our opinion we are actually capable of carrying heavier loads at the end of the 20-year period than it was at the beginning.

Mr. COURTNEY. Well, would I be correct in saying then that in the test which you have described here and the conclusions which you have just—that is, the conclusions from which I have read, you are saying in effect that this design under traffic conditions would improve over the years so far as stability is concerned?

General WILSON. Yes, sir, or putting it a different way——

Mr. COURTNEY. Put it your own way, then.

General WILSON. Were we to have done more compaction, that is, spent more money in rolling during construction, we could have taken some of this early settlement out by doing more during construction. Now, you reach a point of practicality.

Mr. COURTNEY. Yes, sir.

General WILSON. But as I visualize this thing, by doing considerably more rolling, we might have made this curve come something like this [indicating].

Well, let's say along in here, after 8 years, the traffic had given it that same strength.

Mr. COURTNEY. Yes, sir.

General WILSON. So that actually the submaterials under the surface itself were stronger from 8 years on than they were earlier.

Mr. COURTNEY. Than they were earlier?

General WILSON. And there was no failure. It didn't collapse. It didn't break. It didn't move or shear. That is what we have tried to say.

Mr. COURTNEY. Then just to make it clearer in my own mind for the record at least, had you undertaken greater compaction in the initial stages, you could probably—and probably would have—reduced the drop of 1½ inches which you spoke of?

General WILSON. Yes, sir. That would apply to both the rigid and the flexible.

Mr. COURTNEY. That would apply to both of them?

General WILSON. Yes, sir.

Mr. COURTNEY. That is in your paragraphs 47, 48, and 49 of your conclusions——

General WILSON. Yes, sir.

Mr. COURTNEY. Now, you speak of the repairs that would be required under the conditions which you observed in the test.

Now, in the same circumstances, can you tell the committee what you would have had to have done to repair concrete or rigid—you spoke of the intermittent cracks of 1 inch in the surface, in paragraph 47.

General WILSON. Well, I will put it this way, that we have attempted to do this in the statements, both in mine and General Brown's.

Mr. COURTNEY. Yes.

General WILSON. Where General Brown particularly emphasized it where he said that after the test was complete the amount of cracking that was in evidence was normal and not detrimental to the use of those airfields.

Mr. COURTNEY. Fine.

General WILSON. As that is an airfield within the traffic lane itself.

Mr. COURTNEY. Now, with respect to the concrete, which had the same overrun——

General WILSON. That is what he said also.

Mr. COURTNEY. I am looking at photograph No. 7 now. We now know that was overrun in the same way and with the same weights as the flexible was overrun.

General WILSON. Right.

Mr. COURTNEY. Now, if you were required to repair the surface or the slab, the concrete slab, what would be the expense versus the expense of doing whatever was necessary on the flexible?

General WILSON. Within this general area which was given the true traffic test, we don't consider there was any abnormal requirement for repair in either this or this, except for right here at this buried slab.

In other words, neither the rigid nor the flexible would require anything more than the airfield man normally does.

Mr. COURTNEY. Normal maintenance?

General WILSON. Normal maintenance.

Mr. COURTNEY. All right.

General WILSON. The only place, again, was right at this dip here, which we say can be done in a matter of hours for a few hundred dollars.

Mr. COURTNEY. Then in your summary, so far as any significance in the 1-inch depression which you referred to in paragraphs 47, 48, and 49, you attach no special monetary significance to those findings?

General WILSON. No, sir.

Mr. COURTNEY. You do not regard them as significant so far as damage is concerned?

General WILSON. That is correct.

Mr. COURTNEY. That is all, Mr. Chairman.

Mr. OSMERS. Mr. Chairman, could I ask him just one question?

Mr. HÉBERT. Yes.

Mr. OSMERS. Reference was made in your statement, General, or one of the statements, about the cost of repairing flexible strips. I believe in one instance it was a $200 repair and at both ends it was a $1,000 repair.

Was any figure quoted for the cost of making similar repairs to rigid pavements?

General WILSON. The point we were making there, sir, was that the only place within the portion that was given the true test that would require any real maintenance was right at this one point where we had this buried slab junction, which we think we might be able to design and do better on, but we didn't.

Mr. OSMERS. Yes.

General WILSON. That none of the rigid nor flexible portion, other than this one little place, required any. Therefore that is the only place we gave any estimate. We just merely tried to point out that even that is extremely minor.

Mr. OSMERS. Do you have any experience that you could share with the committee, General, with respect to rigid runways that have been in long time use? Have they developed cracks and, if so, how extensive and expensive were the repairs required?

General WILSON. Yes, sir, we have a lot of experience on that. But again I would say it would be better to direct that question at the Air Force——

Mr. OSMERS. All right, sir.

General WILSON. Who have to determine when they want to have a serious repair job done.

Mr. OSMERS. That is all I have.

Mr. HÉBERT. Thank you, General Wilson and General Brown, very much.

Mr. COURTNEY. Mr. Ferry is here.

Mr. HÉBERT. Mr. Ferry.

Mr. FERRY. Yes. Good morning.

Mr. COURTNEY. Mr. John Ferry, special assistant for installations of the Department of Air Force, who has a short statement, I believe.

STATEMENT OF JOHN FERRY, SPECIAL ASSISTANT FOR INSTALLATIONS, DEPARTMENT OF THE AIR FORCE

Mr. FERRY. Gentlemen, with your permission I would like to read into the record the prepared statement I have here and subsequently I would like to call upon two Air Force officers, experienced in the business of flying B–52's, who will be available to supplement and add to the statements I make here from personal experience.

With the permission of the chairman, I would like to read this prepared statement, which presents the view of the Air Force on the Columbus AFB test results and other conditions which affect aircraft operations.

Representatives of the Air Force, including myself, have observed the proof test section at Columbus Air Force Base at various times before, during and after the test rolling. We have studied the report of the Corps of Engineers and concur in this report. It is a clear statement of facts, of conditions and the results. The conclusions drawn from the results of the test and presented by General Wilson and General Brown are generally concurred in.

We do have reservations regarding the probable durability of the leaner mix used in the asphaltic concrete. That is to say, we cannot be sure that the degree of reduced durability of the newer mixes will be in the order of only 2 or 3 years, as compared with a pavement constructed with a richer mix which is considered to have 20-year durability. However, as so aptly pointed out by General Wilson, there is no known accelerated test which can prove or disprove this appraisal.

I would like to present to you certain aspects of aircraft operations which have a definite bearing on OCE's conclusions. You will recall that General Wilson stated that B–52 operational conditions may occur which could cause objectionable roughness in flexible pavement because of differential settlement. Such operations do occur quite regularly. For example:

(*a*) There are many instances where a portion of a runway is used as a taxiway while construction or repair is in progress on the runway or taxi system. This has been brought out by General Wilson's questioning.

(*b*) Under the current alert procedures as established earlier this year, fully loaded aircraft are required to simulate takeoffs at frequent intervals. In these cases engines are run up at full power and are then decelerated. Then the aircraft is taxied down the runway and back to its position on the ramp. Here the runway is subjected to the loading characteristic which occurs on taxiways.

(*c*) Out of the total number of scheduled missions per month a certain percentage will be aborted. Many of these occur at takeoff and the aircraft fail to get off the ground. This means that the aircraft in its fully loaded condition must travel down the runway. The braking and deceleration action involved in such a maneuver exerts severe shearing forces on the pavement. This can and does result in a washboard effect on asphaltic concrete. It becomes most pronounced during hot weather.

(*d*) Frequently aircraft awaiting takeoff are required to clear the runway for an emergency or other similar situation. Here again we have very heavy aircraft taxiing down the runway.

These operational conditions do and will continue to exist. With flexible pavement, we would expect rutting and roughness beyond acceptability with regard to safe aircraft operations.

Attention is invited to the fact that each B–52 takeoff involves (1) an aircraft worth approximately $7,100,000, not counting the value of the payload; (2) a load approaching 500,000 pounds which has to be accelerated to approximately 170 miles per hour on the runway to reach

flying speed; and (3) the lives of the 6 crew members. The successful launching of this weapon requires a high degree of skill by the pilot.

Rough or uneven pavement surfaces have the following effects on our SAC operations:

(*a*) The structure of the aircraft and the precision instruments and equipment are subjected to sharp shocks and jolts.

(*b*) Oscillations are set up in the aircraft, resulting in "porpoising." This causes a redistribution of weight between the front and rear gears.

(*c*) During the latter part of the ground run, the aircraft pitches and bucks so that the pilot cannot maintain full control of the aircraft because he is forced to "hang on" until the aircraft breaks ground.

(*d*) Aircraft are sometimes pitched into the air before they have gained sufficient flying speed to safely leave the runway.

For these reasons, our B–52 and B–47 pilots have much greater confidence when operating from rigid pavements. Such confidence plays an extremely important part in the successful accomplishment of SAC's defense mission.

In summary, it is the Air Force position that all portland cement concrete runways are preferable for the reasons stated; but where a substantial economy is possible by using a combination of rigid and flexible paving it is a reasonable decision to build a center strip of portland cement concrete pavement between the concrete ends, with asphaltic concrete pavement on the sides, both sides.

That is the Air Force position, sir, and with permission I would like to call on General Knapp, who is seated in the rear of the room here, who is the engineer, construction engineer for the SAC contingent. He would give you his experience in a very short prepared statement which will amplify from his own experience some of the points which I bring out as a nonflier.

Mr. HÉBERT. We are very happy to hear the general. Let me ask one question first.

Mr. FERRY. Yes, sir.

Mr. HÉBERT. As to the Air Force's position, you do accept that where an economy is involved, that you could use the asphalt pavement?

Mr. FERRY. Yes, sir.

Mr. HÉBERT. And you would do it?

Mr. FERRY. Yes, sir.

Mr. HÉBERT. But how would you do it if you don't get competitive bids?

Mr. FERRY. We can estimate before we have actually designed the pavement, knowing the comparable costs of the construction of both rigid and flexible in the particular area under question.

Mr. HÉBERT. How do you know, if you don't ask them?

Mr. FERRY. We turn to our friend, the Corps of Engineers, sir, on this and say, "What is your estimate, or engineer estimate of the cost of rigid and concrete per square yard?" And they, based upon their own experience in that area, and frequently after consultation with local contractors, come up with an estimate of cost which if there is a wide differential we would not take competitive bids. If, however, the differential was slight, we would take competitive bids.

Mr. HÉBERT. Well, have you taken competitive bids recently?

Mr. FERRY. In many cases, sir.

Mr. HÉBERT. You are doing that right now?

Mr. FERRY. Yes, sir.

Mr. HÉBERT. There is one thing that puzzles me and that is how estimates don't mean anything.

Mr. FERRY. Good estimators can come up pretty close, sir.

Mr. HÉBERT. There is no reason to have bids or anything, if you can have Government estimators.

Mr. FERRY. There is a difference. The Government estimates under average conditions. He is not affected by the availability of equipment. He is not affected by the lack or ability of the contractor to get other work. In other words, if a contractor is hungry, he may bid lower than a contractor who has plenty of work on his books for the next 6 months. So nobody can ever foresee what the actual contract bid will be. We can only make our best estimate on average conditions.

Mr. HÉBERT. That is the point I am making. If you don't actually get the bids you don't know what the savings will be.

Mr. FERRY. Again I point out to you, Mr. Hébert, that if the estimate of cost has a wide differential between the two, it is obvious that they can't be pulled together by the bidding. If there is a narrow differential between the cost estimates, it is clear that it would be wise to take alternate bids.

Mr. HÉBERT. Well, what percentage range would you consider——

Mr. FERRY. If they came in within 10 percent of each other, sir, I would think it wise indeed to take alternate bids.

Mr. HÉBERT. That would be on the estimate. Of course, the next Congress, as you understand it, will be very conscious of the word "spending."

Mr. HÉBERT. I haven't seen any Air Force officers offer themselves for election. They don't have to face the spending issue.

Mr. FERRY. I offer no comment, Mr. Hébert.

General Knapp, would you come forward, and General Kingsbury.

Gentlemen, I would like to introduce, if I may, Gen. James B. Knapp, who is the installation engineer for SAC, and General Kingsbury, who is the 47th Air Division commander stationed down at Roswell, N. Mex. Both of these are experienced pilots in their own right and can speak from personal experience.

Mr. COURTNEY. General Knapp, your first name?

General KNAPP. James B.

Mr. COURTNEY. And, General——

General KINGSBURY. Kingsbury, William Charles.

Mr. HÉBERT. All right, proceed.

Mr. COURTNEY. Gen. James Knapp and Gen. William Kingsbury, of Roswell, N. Mex.

Mr. HÉBERT. Proceed.

General KNAPP. Mr. Chairman and members of the subcommittee, it is a privilege to be able to speak to you today on this subject because as our aircraft become more costly and complex, it is important that we devote more attention to the technical and operational sufficiency of the base from which our aircraft and crews operate.

In preparing this statement, I had access to the content of Mr. Ferry's statement, and will repeat items which he has mentioned only where it is considered important for emphasis.

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My remarks are based on 8 years and many hundreds of hours of personal experience with heavy bombardment aircraft. I should like to point out that I am not currently associated with aircraft as is General Kingsbury, who can speak more accurately on the problems encountered in B–47 and B–52 aircraft.

It is common for engineers, in speaking of the aircraft-pavement relationship, to think in terms of the influence of the aircraft on the pavement; that is, how much does it depress the pavement? How long will the pavement last under continuous usage? I would like to consider with you the effect of the pavement on the aircraft and crew.

Modern heavy bombers weigh nearly 250 tons when fully loaded, and, under some conditions, must accelerate to 170 knots, or approximately 200 miles per hour, on the ground before they become airborne. From these two factors, you can see easily, I am sure, that the most important characteristic in a pavement, after the basic strength is assured, is surface smoothness. Surface roughness results from several causes:

1. Inadequate control at the time of laying of the pavement.
2. Patching.
3. Uneven settling of pavement.
4. Unequal settling at the junction between pavement of two different design standards or types.

Regardless of the source of the roughness, it produces an oscillating effect in an aircraft taking off which we call "porposing" and is a completely unsatisfactory condition.

The life span of a "porpoise" runs something like this. The front gear passes over a hump or a hollow and, as a result, the fore end of the aircraft is pushed slightly higher into the air than it should be. Just as the fore end begins settling back toward the pavement, the rear gear crosses the same unevenness, with the result that as the front is at the lowest point, the rear of the aircraft is at its highest point. These two events occur in periods of time measured in seconds or less. The springing action of the gear causes the fore and aft oscillation up and down of the aircraft to continue for a significant period of time, and on flexible runways, additional humps or hollows are developed by the aircraft bouncing on the pavement.

This condition continues to get worse as time goes on. The effect on control response by the pilot varies in severity from moderate annoyance to a very dangerous situation in which control of the aircraft is momentarily impaired or lost. In such a situation, the pilot has virtually no control of the airplane, and during this period, his instruments vibrate to the extent that they are unreadable. We have numerous reports filed by our pilots concerning difficulties encountered in maintaining adequate control of their aircraft on rough surfaced runways. Any pavement which places an $8 million airplane and a six-man crew in this situation is unsatisfactory.

From an operational point of view then, we require a pavement surface which will have maximum local smoothness, adequate bearing surface and a maximum life span at the minimum cost.

That concludes my statement, sir.

Mr. HÉBERT. General Kingsbury——

Mr. BATES. How much did you say those planes weigh, General?

General KNAPP. The normal weight of the airplane is 500,000 pounds. During the acceleration, in the initial part of takeoff, the weight on the rear gear is 265,000 pounds.

Mr. BATES. You said tons before.

Mr. HESS. Two hundred and fifty tons, he said.

Mr. BATES. What was the figure you used there?

Mr. HESS. He said 250 tons.

General KNAPP. The fully loaded aircraft weighs 250 tons, or 500,000 pounds.

Mr. BATES. These tests were predicated on 240,000 or 275,000?

Mr. FERRY. They were predicated, sir, on a gear loading of 220,000 pounds, on the gear, which is half of the weight of the airplane, with the compensating lift gained by the lifting of the wings as it passes down the runway, which depresses the loading upon the gear.

Mr. COURTNEY. General, I have a question to ask you, General Knapp.

In view of the importance which you attach to this porpoising and other conditions on the surface of your runways, do we understand that you have no problems with concrete pavements now in use?

General KNAPP. As a matter of history, we have had less trouble with rigid pavements than with nonrigid pavements.

Mr. COURTNEY. General, I will ask you in view of the position which you have taken and which I respect whether or not in the circumstances and attaching the significance which you do to smooth surfaces, has your department conducted any tests or gone into the establishment of any newer design criteria for concrete or rigid pavement? It seems as this matter is presented here by the Air Force today that we are testing only one thing. I am wondering whether or not you have made any tests on concrete pavement for design, substructure or anything?

General KNAPP. I am of the opinion that the current test applied the same load conditions to a rigid pavement as it did to a nonrigid pavement.

Mr. COURTNEY. Well, I would have to say respectfully that I understood the general to distinguish very carefully and say that his test was directed and his conclusions related only to flexible pavement.

Mr. FERRY. May I interrupt?

Mr. COURTNEY. Am I correct or incorrect in that?

General WILSON. The test was designed to test the flexible pavement, but in our conclusions we pointed out some incidental observations on the rigid portion that was trafficked.

Mr. COURTNEY. Then to continue, General Wilson, would the record then reflect this: That the tests which you made of the concrete strip in the same operation in which you tested the flexible strip will give you an opportunity of evaluating a concrete surface and that from that premise you were able to reach the conclusion with respect to the total design which you have indicated to the committee? Total design means 75-foot concrete strip under certain conditions. And asphalt the rest of the way.

General WILSON. Let me answer it this way: The flexible pavement consolidated or subsided an average of 1¼ inches. The rigid pavements subsided approximately one-third that amount. Both pavements

withstood the tests of the straightedge and the variation from a certain plane assembly in our opinion, except for the junction which we said could be corrected.

Mr. COURTNEY. Yes.

General WILSON. So the rigid pavement did retain the smoothness characteristics that we are required to build in after the test was over, but except for 1 or 2 isolated sections so did the flexible.

Mr. COURTNEY. Then to get this straight for the record, at least so conclusions can be presented by the subcommittee, would we understand then on this side of the table that the test at Columbus was not only a test of the flexible pavement, but was likewise a test of the concrete pavement and that from that total operation on those two different kinds of pavement you reached your conclusion which is expressed here this morning, as to the type of design that would meet the requirements for B–52 traffic?

General WILSON. Yes, sir.

The test was not as thorough a test on the rigid as it was on the other, but from the results of what we observed, we concluded that we would or should agree with the Air Force that it was good insurance to have a rigid strip down——

Mr. COURTNEY. Under the conditions you specify?

General WILSON. Yes, sir.

Mr. OSMERS. Mr. Chairman.

Mr. HÉBERT. Yes, Mr. Osmers.

Mr. OSMERS. I was very much interested in the testimony with respect to porpoising, and I can see how that would present a hazard, both actual and mental, and it should be avoided to the greatest possible extent, but, as I understand the statement that was made here by General Brown—and I may not have the right reference, but on page 9, toward the bottom of the page, it seems that at the completion—I am now reading from page 9:

> At the completion of the testing the final surface of the flexible pavement within the test lane still met the straightedge requirements in the longitudinal direction, except in this area adjacent to the transition.
>
> In the transverse direction, the surface exceeds the allowable departure from the 12-foot straight edge by about a quarter of an inch.

Now, possibly oversimplifying, Mr. Chairman, but it would seem from the testimony of General Brown a few moments ago that the possibility of porpoising on a flexible pavement after 20 years of use would be very, very minimum.

Now, is that so, would you say, General?

Mr. FERRY. May I comment on that, sir?

Mr. OSMERS. Please do.

Mr. FERRY. I think, if our pavement, flexible pavement, were subjected only to what General Brown and General Wilson refer to as normal B–52 flying——

Mr. OSMERS. Yes.

Mr. FERRY. I think that is probably a fair statement that you made.

However, when you throw in what we call the incidental taxiing, which means that the loaded plane with no uplift effect from the wings whatsoever, runs in a very narrow and confined portion of the runway, we are convinced that over the period of time we will get longitudinal ruts resulting not from the normal flying operations, but from the incidental taxiing.

Mr. OSMERS. Well, now, Mr. Chairman, in commenting on that reply, in this same section I believe that General Brown's statement indicates that what you say is so, even in the tests that were conducted, and that is that you did get a certain amount of rutting and that on the transverse the surface exceeded the allowable departure from a 12-foot straight edge by a quarter of an inch, indicating that what you say, sir, is true with respect to the transverse measurements.

However, I don't feel that rutting, even that slight—that rutting would cause you to porpoise. Now, I could be wrong about that, but if you are going in a straight direction and porpoising in a taxiing operation, I shouldn't think it would be particularly significant one way or the other.

In takeoff it would be very significant, I should think.

I am not trying to be for or against it. I am trying to take the testimony of General Brown and to see whether that indicates that porpoising does happen or not.

Now, according to the reading of that testimony, it met the longitudinal requirement, which requirement, I assume, was to prevent porpoising, while it did not meet the rutting requirement which would be transverse to this.

Mr. FERRY. You are quite correct, Mr. Osmers. And if I would use a very homely simile, we fear this rutting which could develop would have about the same effect on an airplane as the same feeling as when your automobile hits a trolley track. It throws it a little bit as it is going at this speed of 150 to 175 miles an hour down the runway.

Mr. OSMERS. Yes. That I think will be so.

Mr. HÉBERT. General.

Mr. FERRY. General, would you just express your own views as a commander of a number of young men?

General KINGSBURY. Mr. Chairman and members of the committee, I would like to point out that I am in no sense an engineer. I have no connection with installations whatsoever. I command a SAC combat-ready wing of B–52's, and I have also had a wing of B–47's until just recently.

My concern therefore, as far as the runway is concerned, is twofold. One is for the safety of the investment that I have in the 49 $7 million B–52's and for the lives of the crews that I have assigned to my organization.

Secondarily, it is to be sure that I can accomplish my war plan mission. Both of those are jeopardized at the present time at my base, at Walker Air Force Base, where I have I believe one of the roughest runways within the Strategic Air Command.

Safety wise, the problem of porpoising is twofold. It affects the structural safety of the aircraft. For instance, in our case, on our outrigger gears, the little gears that are out on the ends of the wings—they are approximately 155 feet, that distance between the two outrigger gears. As the aircraft porpoises, they get quite a bit of stress out there and they are not quite as strong as the main gear of the aircraft. So we have, within the last 6 months out there, broken off 3 outrigger gears and we have broken 18 shimmy dampeners that are attached to those gears to prevent them from shaking as the aircraft takes off. That is the structural part of it so far.

Now, on the safety of flying the aircraft off during porpoising, the serious condition we have run into is that in many cases both the B–52 and the B–47 have been thrown into the air as they approach their normal takeoff speed at anywhere from 6 to 7 knots below the speed that they would normally take off. This, in a heavily loaded jet aircraft is extremely hazardous. If the pilot is not on his toes—and I mean does not take positive action at the time that aircraft is airborne—he can stall the aircraft and it will go back into the ground and you lose an airplane and crew.

These aircraft are extremely critical at heavy weights, just at the time they become airborne. So it is very important that that aircraft not leave the runway until it reaches premeditated, calculated speed for on-strike we call it, that is the time it is airborne. If it comes off before that, you have a real good chance of losing an airplane and crew. We have not lost any airplanes and crews due to this.

Mr. HÉBERT. Walker Air Force Base is an asphalt runway?

General KINGSBURY. Yes, it is a SAC Division.

Mr. HÉBERT. I say asphalt runway, sir.

General KINGSBURY. Yes, sir, it is asphalt.

Mr. HÉBERT. Flexible asphalt?

General KINGSBURY. It was built during World War II and it has had several extensions on it.

It has had an overlay on the runway. But I believe, General Knapp, it is still stressed for only 100,000 pounds, is that correct?

General KNAPP. Yes, sir.

General KINGSBURY. It has never been built to B–52 criteria.

Mr. HÉBERT. Well, then, you can't use that as a fair example.

General KINGSBURY. I am just giving you, as I said, Mr. Chairman, what the hazards are on a rough runway. I am not saying whether asphalt or runway——

Mr. HÉBERT. But on a runway that is not built to occupy the plane?

General KINGSBURY. Yes, sir.

Mr. HÉBERT. Naturally a field would be more hazardous, too, if you didn't have any runway. You could tell us about that, but here you are using a runway which is not adequate to sustain the 52 or the 47.

General KINGSBURY. That is absolutely true, Mr. Chairman.

Mr. HÉBERT. Yet if it was built to stand it, then you wouldn't have that problem.

General KINGSBURY. If it was a smooth runway we would not have that problem.

Mr. HÉBERT. Naturally. I want to ask again in connection with the alternate bidding.

Mr. FERRY. Yes, sir.

Mr. HÉBERT. What objection would the Air Force have to get alternate bids? It wouldn't cost you anything.

Mr. FERRY. It only means you have two designs to prepare in order to take alternate bids and you put the contractors to the expense of the bidding on alternates where if there is a great differential between the two estimates, of course, it would seem to be an unnecessary expense on the part of the contractors.

Mr. HÉBERT. I never heard any contractor complaining. The contractors are the ones in here complaining they are not given a chance.

Mr. COURTNEY. The contractor doesn't have to bid on alternates. He can bid 1 or 2 alternates, just as he chooses; isn't that right?

Mr. FERRY. Yes; but most smart contractors bid the alternates because they never know the intention of the owner. Most smart contractors do.

Mr. HÉBERT. You mean the Air Force intention is that vague that the contractor doesn't know what they want?

Mr. FERRY. He doesn't know how much they would be willing to pay and how much they think the thing is necessary.

In other words, if he is going to be asked to bid on a job with an alternate, a smart contractor will always bid the alternate.

Mr. HÉBERT. During these many years of hearings, Mr. Secretary, we have never heard a contractor complain about being offered a chance to bid.

Mr. FERRY. Well, there have been times that I have heard the expression.

Mr. HÉBERT. What is the position of the Air Force in, say, a set area where a contractor would come in and ask to bid? Would you tell him he couldn't bid?

Mr. FERRY. No, sir; we would not.

Mr. HÉBERT. Then he would have a chance to bid as an alternate; wouldn't he?

Mr. FERRY. He would indeed, if there was a design prepared.

Mr. HÉBERT. If you allowed the alternate.

Mr. FERRY. If there were a design prepared, sir.

Mr. HÉBERT. Well, you would have to prepare two designs then to get your Government people to give an estimate; wouldn't you?

Mr. FERRY. They don't prepare it in the detail that you do when you take bids for actual contract work.

Mr. HÉBERT. All the more that it is not an accurate estimate. It is a guess.

Mr. FERRY. No; it isn't a guess. It is better than a guess, surely.

Mr. HÉBERT. Not shaded very much better than a guess.

Mr. FERRY. Oh, I would feel that it was a reasonably good estimate. Engineer estimates in experience come within 10 to 15 percent of the bid prices usually. Is that a fair estimate, General?

General WILSON. Yes, sir.

Mr. FERRY. And if you can estimate within 10 percent, 15 percent of what the contractor is going to bid, that is a pretty good estimate, sir.

Mr. HÉBERT. All right. Knowing from experience with Government agencies, it is not infrequent that the estimate of the Government agency is far in excess or far below what the actual bid is after competition. That is not infrequent.

Mr. FERRY. It is not infrequent.

Mr. HÉBERT. Why should the Air Force be set apart from that general rule?

Mr. FERRY. Well, I would like to disclaim for the moment. The bids are taken by our agent, the Corps of Engineers. We do not take the bids.

What I am saying is that on common work, such as concrete pavements or asphaltic, flexible pavement, things that are very well known to the experienced contractors—they know their costs extremely well—the Government estimate is usually quite close to the final bid price.

Now, on a complicated structure, let us say a building that hasn't been built before of that type, there you may find a fairly wide variation between Government estimate and contractor estimate. But on things that are as well known as paving, roads, the bids come in pretty close, sir.

Mr. HÉBERT. I am not going to labor the question any longer. But certainly the estimate in the first hearing we had on this was a savings to the Government of $50 million when you were taking the alternate bids and eliminated the differential. I think that is correct; isn't it?

Mr. HESS. Yes.

Mr. FERRY. I think we have learned considerably in the passage of years, Mr. Hébert. I think we have gone to the conclusion which was expressed today by General Brown, General Wilson, and myself, that given a good center strip of rigid pavement we do not feel that there is a requirement for going beyond that unless there is a saving to be made.

Mr. BATES. Mr. Chairman.

Mr. HÉBERT. Yes, Mr. Bates.

Mr. BATES. Mr. Ferry, what is the difference in cost between the lean and the rich mix?

Mr. FERRY. I can't answer that, sir. It is small. It is very small, but I would ask General Wilson if he would care to express his opinion.

General WILSON. It isn't a question of costs there, sir. We were trying to get characteristics of the pavement. I would say they are basically about the same cost between the lean and the rich.

Mr. BATES. Well, the richer mix is more durable; isn't it?

Mr. FERRY. Softer, sir.

General WILSON. More durable.

Mr. FERRY. It pushes.

General WILSON. But also less able to carry the high tire pressures.

Mr. BATES. Mr. Ferry, if this test had been held at Great Falls, Mont., instead of Columbus, would there have been a difference in the results?

Mr. FERRY. I don't think there would have been any difference at all.

Mr. BATES. You don't think that the temperature aspect would make any difference?

Mr. FERRY. Frankly, I don't.

Mr. BATES. Does the Army agree with that?

General WILSON. Yes, sir.

Mr. BATES. Did the asphalt people concur with the site for the test?

Mr. FERRY. Yes, sir.

Mr. BATES. They thought it was satisfactory.

Mr. FERRY. They didn't comment specifically upon the site. They made comments on the proposed tests of one sort or another, but they didn't comment to my recollection specifically on the site.

Mr. BATES. They didn't object to it?

Mr. FERRY. They didn't object to it.

Mr. BATES. To the best of your knowledge?

Mr. FERRY. No.

Mr. HÉBERT. Mr. Hess.

Mr. HESS. I am addressing this question to both General Kingsbury and General Knapp. I take it you are both SAC commanders?

General KNAPP. General Kingsbury is a commander. I am a staff officer in headquarters.

Mr. HESS. I mean you are familiar with a lot of the SAC bases?

General KNAPP. Yes, sir.

Mr. HESS. Are there any SAC bases where the strip is used for taxiing purposes and that there are no taxiing strips?

General KINGSBURY. I know of none. Now, at Walker we have used our primary runway rather extensively during periods of failure of our taxiways.

Mr. HESS. That would be the only time you would use it, though, General?

General KINGSBURY. Except for this Cocoa alert that Mr. Ferry mentioned. At the present time we are exercising six aircraft at maximum gross weight on the runway, on an average of about one aircraft a week, and that is at maximum gross. That is about 450,000 pounds.

Under the SAC alert concept, to test the ability of our aircraft and crew is to get off in a minimum of time, we give them three tests. We have an Alpha- and a Cocoa- and a Bravo-type alert. The Alpha, the crews get in their aircraft ready to start engines, and that is it. They have to do that within a period of less than 20 minutes.

On a Bravo, they get in the aircraft and actually start their engines ready to taxi.

On a Cocoa-type alert, they actually taxi the aircraft out to the end of the runway, full power, accelerate the aircraft, start rolling, and then cut their throttles, roll down the runway, usually about a third of the way down the runway, turn off the taxi strip and back.

Mr. HESS. So that is done on all SAC bases, I presume?

General KINGSBURY. Wherever they have aircraft on a ground alert; yes, sir. And that is on practically all SAC bases at this time.

Mr. HESS. So that on all SAC bases it would be absolutely necessary to have this rigid strip on your runway?

General KINGSBURY. Well, certainly a strip that would bear up under that type of operation.

Mr. HESS. Yes.

General KINGSBURY. Yes.

Mr. HESS. What I am driving at is to find out what bases would not need the rigid strip. I have seen a number of bases where there are taxiing strips.

General KINGSBURY. Yes, sir.

Mr. HESS. Going off of the runway at numerous intervals.

(General Kingsbury nods.)

Mr. HESS. And I can see no reason why they should have a rigid strip through the center of the runway there.

General KINGSBURY. I feel that after our parking area and our taxiways are rebuilt to withstand this type use, then we should have very limited need for using the runway as a taxiway, except in the case of an occasional emergency. I don't see any use for it except that.

Mr. HÉBERT. Anything further?

Mr. COURTNEY. Mr. Chairman, one question of General Kingsbury.

Mr. HÉBERT. Mr. Courtney.

Mr. COURTNEY. General, I understand that there is a proposal now to repair Walker Air Force Base by a 75-foot strip of concrete in the center of your principal runway. I guess there is more than one runway, isn't there?

General KINGSBURY. That is correct. We will be opening bids, I believe this month, for a strip of concrete down the middle of our long runway which is 13,000 feet long. We have 1,000 foot extensions on each end of the runway at the present time. I think that is standard practice now in construction.

Mr. FERRY. Yes.

Mr. COURTNEY. That is all.

Mr. HÉBERT. Thank you, gentlemen, very much.

Mr. FERRY. Thank you, gentlemen.

Mr. HÉBERT. The committee will recess until 2 o'clock at which time we will hear the Navy.

(Whereupon, at 12:15 p. m., the subcommittee recessed, to reconvene at 2 p. m., the same day.)

AFTERNOON SESSION

Mr. HÉBERT. The committee will be in order.

Mr. COURTNEY. Mr. Chairman——

Mr. HÉBERT. Mr. Courtney, before you begin, I want to ask Mr. Ferry a question.

Mr. FERRY. Yes, sir.

Mr. HÉBERT. Mr. Secretary how much paving has been constructed since the committee requested that the Air Force defer, until we had these tests?

Mr. FERRY. Answering from memory, sir, none.

Mr. HÉBERT. None at all.

Mr. FERRY. None at all. There have been some repair work done, but there has been no new paving contracts, as I understand.

Mr. HÉBERT. There have been no new paving contracts, as you understand.

In other words, you adhered to the request of the committee?

Mr. FERRY. That is right. I am talking from memory, sir. Let me make a check on that, so I am 100 percent——

Mr. HÉBERT. Make a check on it.

Mr. FERRY. I will, sir.

Mr. HÉBERT. Mr. Courtney——

Mr. COURTNEY. Mr. Chairman, we have the Bureau of Yards and Docks of the Department of Navy present. The Bureau has prepared a report on rigid and flexible type pavements for Naval and Marine Corps air stations, dated May 1958, which I would ask be incorporated in the record at this point.

(The document referred to follows:)

DEPARTMENT OF THE NAVY REPORT ON RIGID AND FLEXIBLE TYPE PAVEMENTS FOR NAVAL AND MARINE CORPS AIR STATIONS

PRESENT REQUIREMENTS

The establishment of pavement design criteria is a continuing process. Standards are revised, changed and supplemented as they become obsolete because of progress in the development of aircraft and related installations. Jet aircraft having tire pressures of 250 pounds per square inch are being replaced with new aircraft having tire pressures of 300 to 400 pounds per square inch. The gross weight of planes has been correspondingly increased. One cannot today design pavements for planes that either are or will soon become obsolete.

For the now foreseeable future, pavements must be constructed to accommodate the unlimited traffic of the following extreme two classes of aircraft loadings:

Class 1. One hundred thousand pounds on each of two sets of dual tires at 200-pound-per-square-inch tire pressure, the tire spacing for each set duals being 30 inches on center. This is equivalent to B–47 loading.

Class 2. Forty-four thousand pounds on each of 2 sets of dual tires at 400-pounds-per-square-inch tire pressure. This is 22,000 pounds on each tire. There are 2 sets of dual tires, the spacing for each set of duals being 28 inches on center.

The overall thickness of a flexible type pavement is the sum of the thicknesses of the three layered components; subbase, base course, and asphaltic concrete surfacing. This combined or overall flexible pavement thickness is that which is required to sustain the unlimited traffic of the No. 1 class of aircraft of the foregoing 2 classes. Pavement failure under class 1 traffic may be failure of the natural ground or fill (subgrade), the subbase, the base course, or of the asphalt surfacing.

The shearing resistances (or degrees of toughness) of the layered components of the flexible type pavement must meet the most severe requirements of class 1 and class 2 aircraft. Class 2 governs in this case since it produces greater shearing stresses in the asphaltic concrete surfacing and the base course than class 1 aircraft.

A fact that must be appreciated is that failure of any one of the layered components or of the subgrade leads to failure of all of the other layered components if repair is not immediate. The chain is no stronger than the weakest link.

The requirements posed by classes 1 and 2 aircraft are easily met in the case of concrete pavement of adequate thickness, constructed on a firm, well compacted subbase of adequate thickness and stability.

An additional requirement of major importance is that the pavement in all areas where the jet aircraft are not in rapid motion (so-called critical areas) be very resistant to the deleterious, combined effect of heat and blast. The solvent action of hydrocarbon fuels is a problem of lesser importance.

The need for continuous and uninterrupted operations is the principal requirement. Pavements must be designed to guarantee the lowest possible minimum of time out for repairs. The cost of actual contracts for periodic maintenance and emergency repairs is a minor item as compared to the cost, dollarwise, of halting regular operations of costly aircraft and delaying training schedules. This greater cost is absorbed by Naval Operations and does not appear in the cost records that are usually kept for maintenance and repairs. It is estimated that the minimum cost (to operations) of immobilizing an active major jet air station is $10,000 per day.

DIFFICULTIES ENCOUNTERED

Owing to the urgent need for uninterrupted operations, there is the natural tendency to postpone repairs to pavements until there has been such general and widespread pavement deterioration that a major contract is required to reconstruct it. This condition multiplies cost and presents a real hazard to pilots and crews.

Another contributing factor to the postponement of pavement repairs is that it is not feasible to obtain on short notice and in quite small quantities the high quality of materials that is guaranteed in specifications for major projects. This problem has been most perplexing in the patching of small areas of flexible type (asphalt-surfaced) pavements where local pavement failure occurs.

It is obviously not feasible to employ commercial laboratories to make tests for the control of the Marshall stability and other properties of any 30 cubic yards of asphaltic concrete required for an immediate repair and the responsible public works officer under such circumstances must use whatever the local asphalt mixing plant has to offer which usually is material used for surfacing local highways. In Navy experience no such problem is encountered when small repairs of concrete pavement are required. Materials of standard quality for resealing joints are readily available, portland cement is a standard product and it is entirely feasible to prepare concrete mixes of high quality in very small quantities.

Another serious problem is a growing scarcity of aggregates, suitable for the most stable types of asphaltic concrete mixes, in many localities. A tire pressure of 400 pounds per square inch exerts a pressure of at least 450 pounds per square

inch on the pavement which produces a shearing stress of about 150 pounds per square inch in the surfacing and the top few inches of base course immediately under the surfacing. Tests sponsored by the Bureau of Yards and Docks and made by the CAA at its Indianapolis laboratory indicate that a shearing resistance of 150 pounds per square inch is not usually attained with many commonly used base course materials.

Projection specifications, prepared for the Navy by engineering consulting firms have required generally that the aggregates for asphalt surfacing have a Los Angeles wear of not more than 45. These specifications up to the present time have had reference to tire pressures of 250 pounds per square inch. For all future construction, all aggregates for surfacing must be selected to meet all requirements posed by tire pressure of 400 pounds per square inch. It is very unlikely that aggregates can be found in quantity in many localities that can surpass in quality those already used in past construction for the lower tire pressures.

The measured stability of asphaltic concrete mixes of wartime construction was about 1,000 pounds, on the average with the Marshall test. This was found to be inadequate for jet aircraft of 250-pound-per-square-inch tire pressure and for jet aircraft traffic, the asphalt-surfaced pavements of World War II vintage were resurfaced with asphaltic concrete having a minimum Marshall stability of 1,500 pounds. This minimum was later increased on actual projects to 1,800 pounds. Now the question arises as to the possibility of increasing this requirement to 3,000 pounds for jet aircraft having 400-pounds-per-square-inch tire pressures. The likelihood of accomplishing this seems remote except in a few favorable localities. To consistently obtain a minimum of 1,800 pounds, a relatively low bitumen content has been required. Further reduction in bitumen to attain much higher stability seems hopeless for the mixes would then be so dry that wind would blow them away.

Insofar as tire loads (pounds) and not tire pressures (pounds per square inch) are concerned, flexible type pavements have been most adaptable to stage construction and it has been economical to overlay them progressively for progressively heavier aircraft. However, this adaptability does not extend to the condition of progressively higher tire pressures. Heavier and heavier aircraft of moderate tire pressures require thicker and thicker flexible pavements which present no serious problem from a construction standpoint.

However, higher and ever higher tire pressures with the development of new aircraft poses a most serious problem of constructing tougher and ever tougher flexible type pavements and in this nature has set definite limitations. It is extremely wasteful also to overlay existing asphalt-surfaced pavements not because greater pavement thickness is required but because a pavement of greater toughness can be had only by burying the old pavement under a tougher new one. If the old one has been sufficiently tough the new one would not be required. Concrete pavement presents no such problem. It has all the resistance to the scuffing, torsion, and abrasion of high-pressure tires of any aircraft yet envisioned.

THE SERVICE RECORDS OF ASPHALT-SURFACED PAVEMENTS

The Bureau of Yards and Docks has asked for and obtained from its district offices the records of performance in service of asphalt-surfaced pavements that were designed and constructed for the use of jet aircraft having tire pressures of 250 pounds per square inch. These pavements have been constructed subsequently to 1950 and the surfacings are of a superior type of asphaltic concrete of high Marshall test stability, made with densely graded, hard and durable aggregates and asphalt cement.

A boiled-down summary of the field reports is shown in the attached table. These reports indicates a general belief on the part of field engineers and inspectors, including both the personnel of firms of consulting engineers and those of civil-service status that the likelihood that asphalt-surfaced pavements can meet the severe requirements of traffic of jetplanes having 400-pound-per-square-inch tire pressures without posing serious risks to plane operations is quite remote. Certainly it is a long jump from 250 to 400-pound-per-square-inch tire pressures and the asphalt surfacings exposed to the traffic of 250-pound-per-square-inch tire pressure aircraft have been taxed to the utmost as the field data clearly show. One must also bear in mind that the field reports have reference to those asphalt-surfaced portions of runways and taxiways that are situated between the concrete paved ends of runways and taxiways.

The Navy takes the position that the best indication of pavement adequacy is performance in service, over long periods of time and under varied conditions with respect to climate and local availability of aggregates and soils. What can be accomplished by contractors generally and under normal or average conditions is a matter of practical importance and what can be accomplished by meticulous care in construction and selection of aggregates of unusual hardness, etc., is a matter of somewhat lesser importance. Navy airfield pavement construction is worldwide and it cannot always be accomplished by the most competent of contractors and with the best of equipment, inspection, and materials.

A flexible type pavement consists of several layered components, built from the ground up; the lowest component being the compacted subgrade and the topmost component being the bituminous surfacing. When one of these layered components fails then the entire pavement fails. The chain is no stronger than the weakest link. The load-distributing power of a flexible type pavement depends both on the overall pavement thickness (sum total of the separate thicknesses of the several layered components) and on its toughness. Very heavy planes require relatively thick flexible pavements ,irrespective of the tire pressure. Very heavy planes having high tire pressures require that the flexible pavement be both relatively thick and also tough. Light jet aircraft having excessively high tire pressures require pavement toughness above all else and this is primarily a Navy requirement. One can always increase the pavement thickness to meet total planeload requirements but one is definitely limited in putting toughness in flexible, asphalt-surfaced pavements. The Navy has about reached that limit at its various airfield locations. It believes that for the new planes having tire pressures of 400 pounds per square inch and for the still newer planes of the future that may have still higher tire pressures, it must pave its entire runways with portland cement concrete which, with normal aggregates that are usually available locally can provide resistance to all manner of stresses, whether compression, tension or shear, that far exceeds the highest tire pressure.

SURVEY OF PERFORMANCES OF ASPHALT-SURFACED PAVEMENTS

In 1950, the Bureau of Yards and Docks prepared new design criteria for asphalt-surfaced pavements required to sustain the unlimited traffic of jet aircraft equipped with tires having tire pressures ranging from 150 to 250 pounds per square inch. All airfield pavement construction subsequent to the year 1950 utilized these criteria. In the latter part of 1957, district public works offices were requested to make careful and thorough inspections of asphalt-surfaced pavements which were constructed at any time during and subsequent to the year 1950. This eliminated from the survey all old pavements built prior to 1950 which had been designed for propeller-type aircraft having tire pressures less than 150 pounds per square inch.

A summary of the reports received from the districts is contained in enclosures (1) and (2) and in still more reduced form in exhibit (A) which is a graphic chart. The conclusion reached is that there has been progressive deterioration of the asphalt-surfaced pavements generally, that this deterioration and faulting is due primarily to the high tire pressures, that the damaging effects of the high tire pressures on the asphalt-surfaced portions of runways (between the concrete ends) tend to be cumulative with time, since repairs cannot be made promptly during normal operations for reasons already stated and that the surface uneveness, raveling, cracking, and rutting, etc., indicate that these same pavements cannot withstand the unlimited traffic of future aircraft having 400-pound-per-square-inch tire pressures without posing such a serious problem of maintenance and repair as to reduce to an intolerable extent the military value of the airfields.

Certainly the performance records under a tire pressure of 250 pounds per square inch warn against the further construction of this type of pavement for a far more severe traffic condition than that to which they have already been exposed. And there is no reason for believing that the stability and toughness of the asphalt surfacing and the base course under it can be improved under the worldwide variable conditions to an extent such that the new and far more severe demands and requirements can be met.

RELATIVE MAINTENANCE COSTS

Enclosures (3) and (4) show comparative costs for repairs of concrete and asphalt-surfaced pavements during fiscal years 1955, 1956, 1957, and to the present time of fiscal year 1958. These are complete records for this period of time and they have reference to only those pavements which either were newly constructed or reinforced subsequently to 1950 for jet aircraft having tire pressures ranging from 150 to 250 pounds per square inch. The cost data do not include the cost of reinforcing the old pavements. This was reconstruction and not repair. The data include all paved areas, aprons, parking areas, runways, and taxiways.

Note that the total of $639,438 spent on the repair of concrete pavements was used for the most part in sealing and resealing joints. Wholesale resealing of old joints was deferred until a more heat-resistant type of seal was developed and marketed. This was realized in 1956 after the Bureau's research laboratory had determined that heat-resistant joint seals were being produced. These were the materials that the Navy had been waiting for. Consequently, joint resealing projects were greatly increased in number, beginning in fiscal year 1956. Joint resealing requires very little equipment and few personnel and thus interferes to only a minor extent with normal aircraft use of the pavement.

The total cost of materials, labor, and profit to the contractor for repairs to the asphalt-surfaced pavements during the same period of time was $2,488,581, about four times the amount spent on a greater yardage of concrete, considering the total yardage of each type of pavement of all naval airfields. Unfortunately, however, this amount spent on blacktop repair is far less than the amount that should have been spent since the repair of many worn pavements of this type is being deferred because of the hesitancy of operations to suspend use of the runways for this purpose.

PAVEMENT RESEARCH BY THE NAVY

The Bureau of Yards and Docks has sponsored and financed research-and-development programs. It has also made extensive pavement evaluation studies at 86 of the Navy's principal airfields, utilizing its own personnel for this purpose. In the conductance of pavement research by contract with firms of consulting engineers, universities, and other bureaus of the Federal Government, it has consistently provided these organizations with its consulting services and technical guidance, made necessary by its responsibilities and nearness to the practical problems.

The following is a list of the major research projects sponsored and financed by the Navy Department through the Bureau of Yards and Docks:

1. The development of especially heat resistant types of concrete pavement. This has been and is being conducted jointly by the National Bureau of Standards and the United States Naval Civil Engineering Research and Evaluation Laboratory at Port Hueneme, Calif.

2. A field study of the limitations and possibilities of prestressed concrete pavement. This was accomplished by contract with the F. R. Harris Co., Inc., in New York City. This project is completed.

3. A study of the relative load distributing powers of different aggregates and soil types used in flexible-type pavements This investigation was made and completed by contract with the Civil Aeronautics Administration at its research laboratory in Indianapolis.

4. A study of materials of high heat resistance and suitable for sealing joints in concrete pavement at runway and taxiway ends where jets power check. This is a continuing investigation and is being made at the Naval Civil Engineering Research and Evaluation Laboratory at Port Hueneme, Calif.

5. Basic research to develop the most accurate and economical engineering principles for use in the design of flexible-type pavements. This project has been sponsored and is being financed jointly by the Navy and Air Force. The study is being made by contract with Columbia University in New York.

6. Basic research to develop principles and equipment for vibratory compaction of subgrades, layered components of flexible-type pavements, and subbases for concrete pavement. An extended study was made and completed by contract with the California Institute of Technology at Pasadena and is now being continued by the Naval Civil Engineering Research and Evaluation Laboratory at Port Hueneme, Calif.

7. Deep-soil stabilization by vertical sand columns. This investigation is being made for the purpose of checking slow settlements of paved areas due to slow consolidation of deep-seated, compressible-type soils (clays and silts) under the weights of earth fills. This study is being accomplished by contract with the firm of Moran, Proctor, Mueser & Rutledge, consulting engineers, New York, N. Y.

Observations on New Type Flexible Airfield Pavement as Reported by the 11th Naval District, December 1957

1. ARRESTING GEAR OPERATION

This operation requires approximately 1,500 feet of runway in front of the gear. This makes it necessary to be on the flexible pavement portion of the runway and in all cases it is placed well down the runway. The rapid stopping of the planes, the gunning of the jet motors to move on after releasing the hook resulting in pavement burn, the replacement of the heavy anchor chain by dragging over the pavement and the slippage of the tractor tires pulling the chain is rough treatment and shows excessive wear on the flexible pavement. The pulling of the chain resulted in complete horizontal failure in the asphaltic concrete surfacing at Miramar, NAS. This operation is expected to be stepped up in intensity in the future. The placement of this gear must be subject to change in location to meet the field's changing requirements. Asphaltic concrete pavement handicaps this operation.

2. CARRIER DECK PRACTICE LANDINGS

This touch-and-go operation is always carried on well down the runway on the flexible pavement portion. The concentration of traffic causes breaking and loosening of the softer surface aggregates in some cases. This loose aggregate can be picked up by suction into the jet motors, causing great damage. Also, many planes drip a small amount of fuel on contact with the pavement; a concentration of this dripping was evident and over a period of time will soften and deteriorate the flexible pavement. The reengagement of full power and the afterburner blast causes burning of the surface and washing away of the surface aggregate. Operations personnel state this operation cannot be permanently established at one point as it must be flexible to move to various locations to meet each field's changing requirements.

3. FLEXIBLE USAGE OF FIELD

In case of an emergency or overloading of the field with aircraft, operations personnel state they would use some runways as taxiways and would use the not-in-use runways as parking areas. Partial flexible pavement runways would prohibit this procedure and seriously curtail full usage of the field in a time of emergency.

4. INADEQUACY OF 1,000-FOOT PORTLAND CEMENT CONCRETE ENDS

Flexible pavement runways with 1,000-foot portland cement concrete ends have suffered the following distresses:

(*a*) Sixty percent of landings are made in the 1,000 feet of flexible pavement past the portland cement concrete end. The concentration of touchdowns has caused some surface abrasions and crushing and loosening of surface aggregate which have been sucked up by the jet motors on takeoff runs.

(*b*) On takeoff the jets usually start their roll on the portland cement concrete end. However, the speed is still very slow at the time of contacting the flexible pavement and engagement of the afterburner results in burning and melting the asphaltic concrete surface and loosening aggregates.

(*c*) Tow target operations require the tow plane to taxi to a point approximately 2,000 feet from the end of the runway and stop on the flexible pavement to attach the tow cable. Upon starting the takeoff with the dragging tow target attached which retards the takeoff, the afterburners are cut in immediately which results in badly burning and eroding the asphaltic concrete surface. This was particularly evident at the MAAS Mojave, Calif.

5. LONGER TAKEOFF ON ASPHALTIC CONCRETE PAVEMENT

Pilots were unanimous in their statements that on hot days a longer ground run was required on asphaltic concrete pavement than on portland cement concrete pavement. This was explained to be due to the air being hotter immediately above the black asphaltic concrete surface than the light colored portland cement concrete surface, which resulted in less efficiency of the motors and less lift to the airframe. The question of softening of the high type asphaltic concrete surface on hot days was debatable although most pilots thought it was a contributing factor.

6. AIORTING AIRCRAFT

The question to pilots on their preference of surface for aborting aircraft was almost unanimous in favor of portland cement concrete as sharp projections from a damaged plane would generally slide on portland cement concrete surface but would dig in on asphaltic concrete surface causing cartwheeling and much greater damage and less chance for survival.

7. MAINTENANCE DIFFICULTIES

Asphaltic concrete runway pavement requires periodic sealing, otherwise the surface will become oxidized and eroded, resulting in surface aggregate being loosened by impact of high pressure tires. This loosened aggregate is a continuous hazard to jet motors. While it is conceded that proper sealing at the proper time will eliminate the oxidation, it is actual case history that the sealing lags far behind the time when it should be done. Operational procedures of the field often make it necessary to defer repairs, resulting in greater repairs at a later date.

Mr. COURTNEY. Mr. Chairman, we have Rear Adm. Eugene J. Peltier, Civil Engineering Corps of the United States Navy, Chief of the Yards and Docks, here present, and Comdr. Waldron M. McLellon, CEC, the same department, Director of the Engineering Division.

Admiral Peltier is here and has a prepared statement, Mr. Chairman.

Mr. HÉBERT. Admiral, proceed.

Mr. COURTNEY. As does Commander McLellon.

STATEMENT OF REAR ADM. EUGENE J. PELTIER, CHIEF OF BUREAU OF YARDS AND DOCKS

Admiral PELTIER. Mr. Chairman and gentlemen, it is the policy of the Bureau of Yards and Docks to use both flexible type pavements and rigid type pavements for Navy airfields. The use of a particular type will depend upon the design criteria and the conditions prevailing at a particular location.

When a Naval or Marine Corps Air Station mission requires facilities for jet aircraft equipped with tires having tire pressures less than 250 pounds per square inch, it is the policy of the Bureau of Yards and Docks to have the critical areas of runways, taxiways, and parking aprons constructed of rigid type pavement, that is, portland cement concrete. The critical areas are the last 1,000 feet of both ends of the runways, the entire length of all related taxiways, and the parking aprons. The pavement in the intermediate sections between the rigid type pavement ends may be of either rigid type or the flexible type depending on economic considerations.

If the air station must accommodate the traffic of jet aircraft equipped with tires having tire pressures that range from 250 to 400 pounds per square inch, it is this Bureau's policy to have the entire lengths of runways, in addition to related taxiways and parking aprons, constructed of rigid type pavement.

This general policy is based on a survey of the performance of pavements under the past and present traffic of jetplanes at major airfields. The Report on Rigid and Flexible Type Pavements for Naval and Marine Corps Air Stations, dated May 1958, which is submitted for the consideration of this committee, is a brief summary of the performance of pavements together with a general analysis of the problem of paving for modern, military jet aircraft that have high tire pressures.

Certain salient facts derived from Navy experience follows:

(*a*) When tire pressures are not appreciably in excess of 250 pounds per square inch, the heaviest of naval aircraft can operate safely in noncritical areas on properly designed flexible type pavements.

(*b*) When tire pressures are appreciably greater than 250 pounds per square inch, now approaching 400 pounds per square inch, toughness of the surface courses becomes the most essential requirement. In these cases, the use of rigid pavement is considered necessary. Toughness of flexible pavements measured by Marshall stability is extremely sensitive to precise control of asphalt in the mix, hardness of stone aggregate, gradation of aggregate, etc. Portland cement concrete, on the other hand, is not sensitive to small variations of its constituent materials. Portland cement concrete is more than adequate in supplying this required toughness. However, in designing and constructing asphalt surfaced pavements adequate for jetplanes having 250 pounds per square inch tire pressures, our experience indicates the limit in toughness has been reached.

The extent of wear and tear of the flexible type pavements certainly does not indicate a good possibility of attaining the degree of toughness required for 400 pounds per square inch tire pressures with asphalt surfacing with the local materials, and construction procedures that are normally encountered.

Carrier type aircraft having these highest tire pressures operate at air stations whose mission is that of direct service to the fleet. Such airfields are in fact our land-based carriers and are of highest importance for training carrier pilots and supporting the fleet. Runway availability, with the least amount of runway downtime, is of major importance at these stations.

Flexible type pavements are still being built by the Navy. Our position is open in this regard. This is evidenced by our future planning, wherein we propose flexible type pavement for consideration at several airfields. However, these activities are for the support of training or patrol planes which do not have high tire pressures.

For the most part, the major maintenance required for rigid type pavements constructed during the past 8 years has been the resealing of joints. This requires very little equipment and few personnel, and normally can be accomplished without inactivating runways. On the other hand, the maintenance for flexible pavements requires the renewal of seal coats, the resurfacing and the patching of asphalt surfaced runways, made necessary by developed surface unevenness. This almost invariably requires inactivation of runways for considerable periods of runway downtime.

Maintenance of rigid type pavement can be carried on under more extreme adverse weather conditions than can repairs to flexible pavements. Furthermore, asphalt concrete of precise mix is difficult to

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obtain in small amounts for repair purposes. This then complicates the problem of obtaining sound repair jobs to flexible pavements, whereas rigid pavements may easily be repaired to a suitable quality.

In summary, it is the policy of the Bureau of Yards and Docks to use both flexible type and rigid type pavements. Navy experience with runways subjected to high tire pressures, over 250 pounds per square inch, has led to the use of rigid type pavements for this type of traffic. However, our position in this regard is open, if it can be demonstrated that flexible type pavements can perform satisfactorily for traffic with high pressure tires.

I have engineers of the Bureau with me here today who are available to answer any detailed questions the committee may have.

Mr. HÉBERT. Admiral, what is the heaviest Navy plane?

Admiral PELTIER. The heaviest Navy plane we have today?

Mr. HÉBERT. Yes.

Admiral PELTIER. May I ask Commander Cardinal, Bureau of Aeronautics.

Mr. COURTNEY. What is your first name?

Commander CARDINAL. William E. Cardinal, commander, United States Navy, Bureau of Aeronautics.

The heaviest aircraft the Navy utilizes today is the Super-Constellation, with a maximum takeoff gross weight of 145,000 pounds.

Mr. HÉBERT. Well, that is not comparable at all to the 47 or 52?

Commander CARDINAL. No, sir.

Mr. HÉBERT. It is a much lighter craft?

Commander CARDINAL. Yes, sir.

Mr. HÉBERT. Now, Admiral, you indicated that you used both the rigid and the flexible, and you also indicated in your opening paragraph the economy factor was important.

(Admiral Peltier nods.)

Mr. HÉBERT. When you put these runways into your stations, do you give alternate bids out?

Admiral PELTIER. We have not, Mr. Chairman.

Mr. HÉBERT. You have not given alternates out?

Admiral PELTIER. No.

Mr. HÉBERT. You make a decision before you find out what the costs are?

Admiral PELTIER. We make a decision first of the mission of the station.

Mr. HÉBERT. Yes.

Admiral PELTIER. If it is going to be patrol plane type, which, as we have indicated we do have some runways under consideration for that type of operation now, the economics of it indicated that flexible type pavement would be much cheaper, so we are going out and designing on a flexible type pavement and taking bids on that basis.

However, if we had a mission where we were using carrier type planes, the mission would determine that this would have to be of rigid type pavement or of concrete because of the higher tire pressures. Our problem is the toughness of the surface. The 400-pound tire pressure is it. It is not the weight of the plane that controls in our particular case.

Mr. HÉBERT. Now, the Navy is concerned particularly with patrol planes for land bases?

Admiral PELTIER. Yes, sir.

Mr. HÉBERT. Not a carrier type, of course.

Admiral PELTIER. Yes, sir; we have some.

Mr. HÉBERT. I mean a carrier-type airplane is a much lighter plane, of course.

Admiral PELTIER. Yes, sir. But has a much higher tire pressure, Mr. Chairman.

Mr. HÉBERT. A much higher tire pressure. Is the Navy concentrated only in the continental United States with their land bases? I mean I want this for the record.

Admiral PELTIER. We recently rebuilt a runway in Midway. We built one in Rota, Spain. The one in Lyautey has been built for some time. We are operating two airfields in Japan. We are operating airfields in the Philippines.

Mr. HÉBERT. You are operating in the Port Lyautey area?

Admiral PELTIER. Yes.

Mr. HÉBERT. You operate there, too. They are really negligible, aren't they, compared to what you have in the United States?

Admiral PELTIER. That is right, sir. It is a small percentage.

Mr. HÉBERT. Mr. Hess.

Mr. HESS. Admiral, have you given any consideration to a rigid or a concrete strip in the runway?

Admiral PELTIER. We have some comments on the Corps of Engineers report that Commander McLellon will state. We have considered that.

Mr. HÉBERT. I would like to have those comments.

Admiral PELTIER. As soon as—we would be glad to give those.

Mr. COURTNEY. Whenever you are ready.

Mr. HÉBERT. We are ready. We would like to hear them.

Commander MCLELLON. Mr. Chairman, I am Comdr. W. M. McLellon, the Director of the Engineering Division, Bureau of Yards and Docks. I will read the statement.

Comments by the Bureau of Yards and Docks on Technical Report No. 3–490, dated November 1958, by the Corps of Engineers, entitled "Proof Test Section, Columbus Air Force Base."

The Bureau of Yards and Docks considers the test of the runway strip at Columbus by the Corps of Engineers to be a valuable contribution to the science of runway design for heavy aircraft. The Navy will consider the use of these data in establishing criteria for the design of fields to support wheel loads similar to those imposed by the B–52.

As previously stated by Admiral Peltier, the problem peculiar to the Navy is the requirement to provide a surface which will resist the stresses induced by the high tire pressures of modern carrier-type aircraft.

The runway test strip at Columbus, Miss., is a flexible pavement constructed of excellent materials under optimum conditions. The materials used show very good hardness, abrasive resistance, and other desirable aggregate properties. In addition, the native materials forming the subgrade are of excellent quality and provide site conditions considered better than the average encountered throughout the world. The quality of pavement developed therefore may not be achieved economically at all locations.

The tire pressures used in the Columbus test were on the order of 250 pounds per square inch. The Navy is concerned with the performance of flexible pavements subjected to tire pressures over 250 pounds per square inch and ranging to 400 pounds per square inch. These high tire pressures impose very severe stresses in the surface courses, stresses much higher than a 250-pound-per-square-inch tire pressure will impose. The surface courses of flexible type Navy airfields have exhibited distress, as noted in the Report on Rigid and Flexible Type Pavements for Naval and Marine Corps Air Stations mentioned by the Chief of the Bureau of Yards and Docks. For this reason, the results of the Columbus test are not considered directly applicable to all Navy construction, particularly for design of pavements for aircraft possessing high tire pressures.

It is noted that the design of the Columbus runway provides a narrow strip of rigid pavement extending 2,500 feet from the full-width rigid pavement, inboard toward the center. Such a strip arrangement is subject to differential consolidation or settlement at the longitudinal joints where the rigid and flexible pavements meet, and causes a step to occur, thus creating another possible hazard to plane operations.

Also, one wheel of a plane on rigid pavement with the other wheel on flexible pavement could cause different braking resistance of the two wheels to occur and increase the possibility of groundlooping. This could happen in single-plane operation, but is more apt to happen in staggered operations such as used by the Navy.

In addition, due to the discontinuity of materials, a large joint or crack may develop as a result of operations or weather conditions, and could permit deterioration of the subgrade due to infiltration of water.

In conclusion, the test at Columbus was conducted on an optimum flexible-type pavement. The results of the test are not directly applicable to all Navy design because test procedures did not include use of high-pressure tires, which Navy experience has found to be especially harmful to the surface courses of flexible-type pavements.

In addition, the concept of a narrow center strip of rigid-type pavement flanked by flexible-type pavement could add to the hazards of plane operation and contribute to the vulnerability of the runway to weather.

Mr. HÉBERT. Mr. Hess.

Mr. HESS. Then you would say, Commander, that it wouldn't be feasible to put a concrete strip through the runway, because of the manner in which you operate planes, in a staggered——

Admiral PELTIER. They take off in dual——

Mr. HESS. That is the principal reason, I presume?

Commander MCLELLON. Yes. I do believe that you must also consider the possibility of wandering of planes, in addition to the staggered operations. Perhaps Commander Cardinal would care to comment.

Mr. HESS. I don't know what you mean by wandering.

Commander CARDINAL. The only comment is that we do operate aircraft in a simultaneous fashion and it is necessary for both aircraft—I should say that the essence of the operation from an airfield, using carrier aircraft, is that the air group be launched and recovered in the minimum amount of time. Therefore, it is necessary to land

aircraft nearly simultaneously and take them off nearly simultaneously.

Mr. HESS. Would you take them off in a formation?

Commander CARDINAL. We take them off in two-plane elements, using both sides of the runway.

Mr. HESS. I see. Well, referring here to tire pressures over 250 pounds per square inch, would there be more effect on a runway with a tire of 400 pounds per square inch on a small plane such as the Navy uses, and a B–52 landing on that same runway?

Commander CARDINAL. I don't quite understand your question, sir.

Mr. HESS. Would there be more effect to the runway surface in landing a B–52 with lesser tire pressure than a smaller plane that the Navy uses with greater tire pressure?

Commander CARDINAL. Yes, sir.

Admiral PELTIER. There is to the wearing surface, Mr. Hess.

Mr. HESS. On the runway?

Admiral PELTIER. It is not the total depth of the pavement that is of concern. It is only the wearing surface that you are concerned with.

Mr. HESS. I see.

Admiral PELTIER. You don't have to have the deep flexible type of pavement. But you have to have a hard-wearing surface so you won't cut through there.

Mr. HESS. And the high tire pressures would cut through?

Admiral PELTIER. That is right.

Mr. HESS. That is all.

Mr. HÉBERT. Mr. Bates.

Mr. BATES. Admiral, you indicated in your statement that the maintenance of rigid type pavement can be carried on under more extreme or more adverse weather conditions than can repairs to flexible pavement. Are you just talking about the joints?

Admiral PELTIER. Yes; mainly. I don't think of any instance now at a station where we have actually replaced concrete as such. If we have replaced concrete, it has been of an overlay type of repair.

Mr. BATES. In other words, if that wasn't the limitation then your statement wouldn't hold, then, would it, because it would be more difficult with cold weather?

Admiral PELTIER. Well, it is a little hard to lay portland cement—a little harder to lay asphaltic concrete in wet weather. You could pour concrete in adverse weather. Temperaturewise, I think your asphalt is a little easier to lay.

Mr. BATES. Now, the commander in his statement indicated the problem of the longitudinal joint between the asphalt and the permanent. Well, you have that same situation, don't you, prevailing when you have less than 250 pounds per square inch? The same situation prevails?

Admiral PELTIER. That is right.

Mr. BATES. Excepting for the load factor?

Admiral PELTIER. That is right.

That is not a load factor; no, sir. It is just a natural inherent problem of joining two different types of materials.

Mr. BATES. So the same situation prevails as you have it today. There is no difference there. I was wondering why you made such a point of that.

Commander CARDINAL. I think I can answer that question, sir. The carrier-type aircraft has got a very narrow tire and the tendency of that tire is to—well, it would naturally be affected by any irregularity in the surface, whereas the B–52 has a larger tire which will climb over the surface without too much difficulty.

Mr. BATES. I understand that. But my point is you have it today when you have less than 250 pounds per square inch.

Admiral PELTIER. We don't have a center strip in any of our runways, sir.

Mr. BATES. No, I am not talking about a center strip.

Commander MCLELLON. That was the comment.

Mr. BATES. How about the one that was on Columbus? I thought you were talking about the Columbus one. Yes, you are. "It is noted that the design of the Columbus runway"—at Columbus, you don't have any center strip.

Commander MCLELLON. Yes, sir; you do, extending 2,500 feet beyond the ends of the runway.

Mr. BATES. That is right.

Commander MCLELLON. This, of course, involves a longitudinal joint on each side.

Mr. BATES. I understand that. Now don't you have a problem today with—you have the concrete and the asphalt meet. Don't you have that problem today?

Commander MCLELLON. Transverse joint; yes, sir.

Mr. BATES. Yes.

Commander MCLELLON. The longitudinal joint, of course, is progressing in the same direction that the aircraft is tracking.

Mr. BATES. Yes.

Commander MCLELLON. And in this case, of course, you have a much longer joint to contend with. It is in the direction of your wheel—the way your wheel is proceeding. So that this could cause a much greater effect on a small wheel, with a narrow tire, than a single transverse joint, where the wheel runs across it and then it is finished.

Mr. BATES. Yes, but you could still have the same type of problem there, for braking, if one wheel is ahead of the other, etc., for the angle, wouldn't that be true?

Admiral PELTIER. I don't think we have any too great a problem of our concrete ends matching on to our asphalt runway center strip. We have a little different transition joint than was shown here this morning.

Mr. BATES. Well, I understand the one they had this morning, anyway, could be fixed up so you wouldn't have the problem.

But you haven't had any problem with your present strips?

Commander MCLELLON. Are you speaking about the joint?

Mr. BATES. Yes.

Commander MCLELLON. None that I know of, sir, presently.

Mr. HÉBERT. Mr. Osmers.

Mr. OSMERS. Admiral, I gather from your testimony and that of your associates that the narrow or comparatively narrow rigid strip in the center of a runway would be of little value to the Navy for the simple reason that you take off and I assume—do you also land in elements of two?

Admiral PELTIER. Yes, sir.

Mr. OSMERS. So that for your purposes this would be a complicating factor and create in a sense two ridges which would have the effect of tossing the aircraft from one side to the other and increasing the possibility of ground looping. Now, I also assume that you do not have the problem of rutting, and talking now of a longitudinal rut in a flexible type pavement due to the heavy load factor?

Admiral PELTIER. No. We do have it because of the high tire pressure which affects the toughness of the surface. The surface cannot withstand it if it is not tough enough.

Mr. OSMERS. Now, that gets to the heart of the basic question that I had in mind. Does this produce, that is, the high tire pressure and the comparatively narrow tire—does that produce rutting from operation along the surface, or does that produce what I would call a gouge when you first land or make those first landing contacts, is the hardness of the tire and the narrowness of the tire having the effect of striking a surface with a hammer and making a dent in it?

Admiral PELTIER. Commander Fales just checked some of these recent operations. I think he could probably give you a little better exact picture of that. I haven't observed those in the last 6 months, but I am sure he can give you the information on that. This is Commander Fales.

Mr. HÉBERT. Commander, give your name to the reporter.

Mr. COURTNEY. Wait a minute. Your first name, Commander?

Commander FALES. I am Comdr. Willard Fales, F-a-l-e-s.

Mr. COURTNEY. And you are with the Bureau of Yards and Docks?

Commander FALES. Yards and Docks; yes, sir.

Mr. Osmers, I have checked our master jet air stations where we are operating these 10 planes in the Navy which have the high tire pressure, between 250 and 400 pounds. In two of them we are in serious maintenance difficulties, namely, our air station at Alameda and our air station at Miramar. At Alameda you will recall it is a major World War II air station, with asphalt paving, and at Miramar we had a World War II concrete X pattern, to which we added in 1951 by the existing criteria concrete ends, 1,000 feet at both ends, with flexible in the middle. It is this strip which is in trouble at Miramar. and at Alameda we also built in 1951 and 1952 flexible pavement with concrete ends. It is this strip in Alameda which is in trouble.

Mr. OSMERS. What is the type of trouble you are having there, Commander?

Commander FALES. Well, the nature of the trouble—we have documented this as of last week and we have some photographs here, along with a plan of the station, showing where on the runway the photographs are taken and each kind of trouble.

At Miramar, 2½ weeks ago, the public works officer in checking the runway found sizable potholes—depressions. It was necessary to close the runway and patch these. And just last week, when he checked again, he found two more potholes. We had to close it just last Friday, the day after Thanksgiving. There were 4 such here, varying in size from 10 foot by 6 foot down to 6 foot square.

Mr. OSMERS. Do you mean the size of the pothole or the size of the repair was——

Commander FALES. This was the size of the repair that was required.

At Alameda, the public works officer—he is our installation officer. He is putting in 150 tons of patch a month at Alameda to keep this station going. It is necessary to patch this runway. He works on it every day, or his road repair crew works on it daily. He has to stop repairs at noontime. So he can only have it in the morning. But operationally they need it in the afternoon.

Mr. OSMERS. Does the difficulty arise, Commander, from the impact of a plane landing or from just the operation of the plane taxiing and taking off?

Admiral PELTIER. May I answer it? It is generally in the landing operation. It is the grooving, the overstressing of the surface. It is not a pothole, or a hammer blow, as you say. It is a long narrow groove that results.

Mr. OSMERS. I see.

Admiral PELTIER. From high tire pressure.

Commander FALES. In addition to the long grooves, there is much tearing of the surface where this tire gouges upon landing. It actually pulls apart, making sizable cracks of considerable length.

Mr. OSMERS. This may be beyond the ability of the witnesses here, or beyond their knowledge: Does the Navy anticipate so far as you know continuation of the use of high pressure tires or an extension of that?

Admiral PELTIER. I am sure they are here to stay.

Mr. OSMERS. Here to stay.

That is all I have, Mr. Chairman.

Mr. HÉBERT. Mr. Lankford?

Mr. LANKFORD. No questions.

Mr. HÉBERT. Mr. Courtney.

Mr. COURTNEY. Just a few questions, Admiral.

I take it from your statement to the committee, you are not wedded to all the seeming conclusions that are contained in this report of May 1958?

Admiral PELTIER. That report was not intended for what it is being used. As Mr. Hébert said this morning, he accidently got hold of it. It was our own internal report.

Mr. HÉBERT. Is there any secret about it we shouldn't know?

Admiral PELTIER. No, sir. Except we probably would have edited it a little tighter if we knew it was going to get this much publicity.

Mr. HÉBERT. That is an honest statement.

Mr. COURTNEY. Then you are not wedded to those conclusions, excepting your conclusions are as you expressed them to the committee today.

Admiral PELTIER. Yes, sir.

Mr. COURTNEY. Now, just a few questions about the carrier-based plane. So we may understand the nature of the problem.

Admiral PELTIER. Yes.

Mr. COURTNEY. You have described the tire pressure. What about the size of the wheel? What about the diameter of it, on these carrier-based planes? Commander?

Admiral PELTIER. Commander Cardinal——

Commander CARDINAL. We have no appreciable variation in the size of tires, comparing the Navy's with the Air Force's, fighter-type aircraft.

Mr. COURTNEY. What in general is the diameter?

Commander CARDINAL. About 22 inches.

Mr. COURTNEY. And that, of course, is a much smaller diameter than what we are speaking of?

Commander CARDINAL. Yes, sir.

Mr. COURTNEY. In B–47's and in B–52's?

Commander CARDINAL. Yes, sir.

Mr. COURTNEY. The size of the tire is different. It is narrower.

Commander CARDINAL. It is only 5 inches, as compared with roughly 24 inches, something in that area.

Mr. COURTNEY. Now, as to the weights with which you are dealing. Now, your carrier based plane is a light plane, two wheels and a nose wheel. And what in general would you say would be the range of weights?

Commander CARDINAL. The range in weights are up to 40,000 pounds.

Mr. COURTNEY. Up to. And generally somewhat below that.

Commander CARDINAL. The average runs around 27,000 pounds.

Mr. COURTNEY. Well, then, let me ask you this. Where you feel that you are required to have a tough surface, as the admiral described—perhaps this would be the admiral's question—the design, then, of the strip, the concrete strip would be different both as to volume and subgrade, would it not?

Admiral PELTIER. Yes, sir, it would.

Mr. COURTNEY. Be what we have been talking about here in the B–52 matter?

Admiral PELTIER. In your weight, when you design for weight, you have to pay much more attention to your total subgrade and base. When you are designing for toughness, that is not as important a factor.

Mr. COURTNEY. Then making comparisons between concrete paving and for that matter flexible paving as has been discussed here this morning by the Corps of Engineers, your design is of a different nature and of a lesser thickness.

Admiral PELTIER. Mr. Palmer can probably answer what our general thickness is. Mr. Palmer is our paving specialist in the Bureau. What is our general thickness?

Mr. PALMER. We are designing the thickness for the heaviest anticipated load, which is 100,000 pounds on dual tires, at 200 pounds tire pressure. The thickness is determined by that factor. And the toughness is determined by the other loading which was in the report here of 44,000 pounds at 400 pounds tire pressure on 2 sets of dual tires. That would be 22,000 pounds on each tire of the dual set.

Mr. COURTNEY. Well, in the latter case, where you are using concrete, what would be the thickness of your slab?

Mr. PALMER. You want to know just the thickness of the slab itself?

Mr. COURTNEY. Yes, sir.

Mr. PALMER. All right. It will run from 10 to 13 inches, depending on the strength of concrete we can obtain, in that locality, and on the subgrade preparation which is contingent or dependent on the ground water, the soil type as well as the ground water level, and the available subbase material that we can compact and put the slab on.

Mr. COURTNEY. Then it is not the same kind of a slab as we were talking about here this morning?

Mr. PALMER. 18 inches? We haven't run into that thickness as yet except for the Air Force.

Mr. COURTNEY. Except where you are doing work for the Air Force?

Mr. PALMER. Yes, that is right.

Mr. COURTNEY. Now, on the order of magnitude of these requirements, Admiral, you spoke of the concrete for the carrier-based operation. What would be the order of magnitude, say, on the number of stations which would require that type of construction?

Admiral PELTIER. Well, all of our coastal stations that are being used for fleet operation, of course, are in that category, but they are not now all concrete. The new one we are building at Lemoore is concrete. That is our latest fleet operating station. The one at Meridian is concrete, but the outlying fields we are proposing to be—at least the secondary runway—of asphalt or flexible.

Mr. HÉBERT. What are you using at New Iberia, Admiral?

Admiral PELTIER. That I think is asphalt there. Let me check.

Mr. PALMER. Concrete.

Admiral PELTIER. That is concrete.

Mr. COURTNEY. For your projections on the other type of field, where you say you will use your heavier plane, the 145,000, how big a program does that envisage?

Admiral PELTIER. Well, as you might know, most of our stations are not one type of an operation. We have both and anticipating change of mission in a lot of cases, you will probably have to design for both. So in most cases we will probably go to the concrete type of runway—reinforced concrete-type runway.

Mr. HÉBERT. May I interrupt there, Mr. Courtney?

In connection with New Iberia, your original mission was a jet base?

Admiral PELTIER. Yes, sir; it has changed.

Mr. HÉBERT. It has changed now to submarine patrol; hasn't it?

Admiral PELTIER. Yes, sir.

Mr. HÉBERT. You would have lighter aircraft there; wouldn't you?

Admiral PELTIER. We will have now. However, at the time it was designed—and I think the contract was let—we had the other mission in force, and we have carried through on that. We have cut the number of runways down, as you recall.

Mr. HÉBERT. Yes. Now, if the mission had been as now, you would not have used the concrete, I presume?

Admiral PELTIER. We certainly would have taken a different look at it. I don't know just the local conditions there.

Mr. COURTNEY. That is all, Admiral.

Mr. HÉBERT. Is that all? Thank you gentlemen very much. We appreciate your appearance today and cooperation.

Mr. COURTNEY. Mr. Chairman, that concludes the Government witnesses on this present subject.

As the chairman has announced, the comments from industry and other interested associations and institutes will be heard on Friday afternoon at 1:30.

Mr. HÉBERT. 1:30 Friday afternoon.

Mr. COURTNEY. At 1:30 Friday afternoon.

Mr. HÉBERT. Before we leave the Government witnesses, I want to ask Mr. Ferry another question.

Mr. FERRY. Yes, sir.

Mr. HÉBERT. General Wilson testified this morning that in all inquiries made by the Corps of Engineers to the Air Force he was informed that 250,000 pounds was the limit; is that correct?

Mr. FERRY. That is the best view that we have, looking as far forward as our design presently can contemplate. I can't promise you 10 years from now.

Mr. HÉBERT. No.

Mr. FERRY. But looking ahead at the next 5 years——

Mr. HÉBERT. No; I am talking about the present. Projected in the future for 10 years.

Mr. FERRY. Looking ahead for 5 years, which is something that we can reasonably anticipate, the weights of the new planes, there is nothing will exceed that 250,000–260,000 pounds.

Mr. HÉBERT. Does that include an atomic-powered airplane?

Mr. FERRY. We have not gotten to a design of an atomic-powered plane, so we could not tell you what the weight of that is going to be.

Mr. HÉBERT. You have no idea, then?

Mr. FERRY. Yes; I have a pretty good idea. We believe it is going to be something less than the B–52.

Mr. HÉBERT. Thank you.

Mr. FERRY. That is only, however, a most tentative picture because we haven't a design.

Mr. HÉBERT. But the present guess is it will be less than 250,000 pounds?

Mr. FERRY. We believe so.

Mr. HÉBERT. Thank you very much, Mr. Secretary.

Thank you, Admiral.

(Whereupon, at 2:45 p. m., the subcommittee proceeded to further business.)

AIRSTRIP PAVING MATERIALS

FRIDAY, DECEMBER 5, 1958

HOUSE OF REPRESENTATIVES,
COMMITTEE ON ARMED SERVICES,
SPECIAL SUBCOMMITTEE FOR INVESTIGATIONS,
Washington, D. C.

The subcommittee met at 1:30 p. m., Hon. F. Edward Hébert (chairman of the subcommittee) presiding.

Mr. HÉBERT. The committee will be in order.

Mr. COURTNEY. Mr. Chairman, I have some information for the record which was supplied by the Department of the Air Force in answer to an interrogatory that was addressed to Mr. Ferry, relating to the amount of payment under actual contract or construction at the present time.

I would suggest it be inserted in the record at this point.

Mr. HÉBERT. That was the question as related to how much——

Mr. COURTNEY. How much was under contract.

Mr. HARDY. Is that in terms of dollars?

Mr. COURTNEY. No, it is in terms of yards.

Mr. HÉBERT. How much in the contracts since the agreement to have the test at Columbus?

Mr. COURTNEY. Yes. Perhaps I better read the letter.

Mr. HÉBERT. I think so.

Mr. COURTNEY (reading):

At the hearings before your committee December 2, 1958, you requested advice as to how much runway paving was placed under contract by our construction agencies since August 1957. In compliance with your request you are advised that all new runway construction placed under contract totaled 1,310,500 square yards of which 133,350 are asphaltic concrete and 1,177,150 are portland cement concrete. These new runways were constructed or are under construction at Lockbourne, R. I., Bong, Wurtsmith, Vandenberg, and Reese Air Force Bases. Due to the early commitments to meet operational requirements and because of the advance status of plans and specifications it was impossible to delay these projects.

In addition, 2,574,450 square yards of runway paving were awarded for contract of which 589,355 are asphaltic concrete and 1,985,095 are portland cement concrete. These projects include such work as:

	Square yards
Runway extensions	1,080,575
Runway widenings	861,577
Runway strengthening and replacement	632,298

I trust that the above information is what you desire.

Sincerely yours,

JOHN M. FERRY,
Special Assistant for Installations.

The letter is dated December 4, 1958.

Mr. HÉBERT. Mr. Courtney, address a letter to Mr. Ferry and ask him the question: How much was suspended, until the test was made.

Mr. HARDY. If Mr. Ferry is here, maybe he can tell us.

Mr. HÉBERT. Mr. Ferry testified the other day, Mr. Hardy, that there were no contracts let, and he would find out. Now, this answer comes in answer to that. There were no contracts let and you just heard the figures read.

Mr. HARDY. I am sorry I missed the testimony the other day.

Mr. HÉBERT. All right, Mr. Courtney.

Mr. COURTNEY. Mr. Chairman, we have invited participation and comment, by the direction of the subcommittee, of the Portland Cement Association, the Asphalt Institute, the National Bituminous Concrete Association, and all who registered an interest in the proceedings.

Because of other engagements it was impossible for this membership to be present at the first hearing of the committee, which was set on December 2, 1958. The meeting was recessed until this afternoon, and we have present the representatives of the Portland Cement Association, who have prepared statements. Mr. G. Donald Kennedy, the president of the association, is prepared to testify, and has a prepared statement, Mr. Chairman.

Mr. HÉBERT. Mr. Kennedy, we will be pleased to hear you.

Mr. COURTNEY. He has a statement in full which he would file with the committee, and a summary which he would present at the moment.

(The introductory remarks of Mr. Kennedy are as follows:)

THE PORTLAND CEMENT ASSOCIATION

The Portland Cement Association is a national nonprofit organization voluntarily supported by more than 70 member companies that manufacture portland cement in the United States and Canada. Its headquarters are in Chicago.

The association's work consists of scientific research, development of new products, promotion, educational work, and technical engineering service for improving and extending the uses of portland cement and concrete.

To carry out this work, the association maintains a headquarters staff of more than 350 scientists, professional engineers, and other specialists and a field organization of more than 450 engineers, architects, and others working out of 6 regional and 32 district offices. Its research and development laboratories at Skokie, Ill., are the largest and most completely equipped in the world devoted exclusively to research on cement and concrete.

Its engineers are in daily touch with design, construction, and maintenance problems throughout the country.

The association is in no way engaged in the manufacture, pricing, or sale of cement, and has nothing to do with commercial practices of the industry.

Representing the Portland Cement Association:

G. Donald Kennedy, president, registered civil engineer No. 234, District of Columbia; civil engineering graudate, University of Michigan; former State highway commissioner of Michigan; former vice president, Automotive Safety Foundation; former president of the American Association of State Highway Officials; member of the Traffic Advisory Committee to the War Department, 1942–45; member, Executive Committee of the Highway Research Board of the National Academy of Sciences; Chairman, 1954–55; member, Air Force Association.

Gordon K. Ray, manager, highways and municipal bureau; registered professional engineer in Illinois; civil engineering gradute, University of Illinois; officer, Corps of Engineers, World War II; coauthor Influence Charts for Concrete Pavements, the basis for present-day airfield pavement design; member, American Association of Airport Executives.

William G. Westall, senior airfield engineer; 23 years domestic and foreign service, Corps of Engineers; lieutenant colonel, United States Air Force (retired); attended Wake Forest College, George Washington University, New York University, and the Engineer School, Fort Belvoir, Va.; member, Society of American Military Engineers; associate member, American Society of Civil Engineers; member, Air Force Association.

OUTLINE

Introduction:
Statement of activities, Portland Cement Association.
Qualifications of witnesses.
Outline of testimony.
Historical review.
Functions and requirements of airfield runways:
Functions of runway.
Requirements of runway.
Pavement deficiencies.
Established competency of concrete airfield pavement.
Comments on the test at Columbus Air Force Base, Miss.:
Asphalt pavement construction.
Asphalt construction time.
Asphalt pavement bitumen content.
Asphalt pavement test observations.
Concrete pavement construction.
Concrete pavement performance.
Summary of comments.
Operational need for concrete runways:
The effects of heavy aircraft upon airfield pavements.
Effects of deficient pavement on high-performance aircraft.
The effect of surface characteristics on aircraft operation.
Objections to a hybrid runway pavement design.
Economy of airfield pavement selection:
Competitive bidding.
The cost of taking alternate bids.
Summary and conclusion.

STATEMENT OF G. DONALD KENNEDY, PRESIDENT, PORTLAND CEMENT ASSOCIATION

Mr. KENNEDY. Mr. Chairman and members of the committee, it is a privilege to appear for the third time before this committee. We wish especially to express appreciation for the rescheduling that has made possible our presence here today.

As Mr. Courtney has said, you have two documents before you. The first is an engineering analysis relating to the Columbus test, including certain charts, which will also be shown on the easel. I hope to highlight this report on the test carefully, but in the interest of your time to move through the document fairly rapidly.

I then hope to present the second document, which is called A Summary by the Portland Cement Association. In the blue-covered document we have a statement as to the work of the Portland Cement Association, which has previously been presented to the committee.

We have a listing of the three representatives who are at this table, including in addition to myself, Gordon Ray, the manager of our highways and municipal bureau, and Mr. William G. Westall, our senior airfield engineer.

The third page of the document is an outline.

And coming to page 1 of the text, I will read the introductory statement.

In past appearances, we have presented documented reasons why portland cement concrete is essential for pavements of military airfields. We have presented the excellent, proven record of concrete as a construction material for such pavement that has made it the logical choice wherever performance, durability, and safety are required. The superiority of concrete pavement is virtually never questioned by those who fly and maintain aircraft.

Today the time has come when we must also speak with clarity and frankness about the failure of blacktop or asphalt pavement on military airfields and in controlled tests. We will present this record to you for your evaluation with the conviction that asphalt as a paving material is simply not suitable for military airfield construction today. It is not acceptable from an engineering viewpoint. It is not acceptable from an operational viewpoint. It particularly is not acceptable to the pilots who have the challenging job of flying the advanced aircraft of today and tomorrow.

Failures of asphalt pavement on military airfields prior to the 1954 hearings led to the selection of concrete for all the so-called critical areas: aprons, fueling areas, and runway ends.

Failures of asphalt taxiways due to "channelized traffic" following the 1954 hearings led to the selection of concrete for these areas on an interim basis, and to the test at Kelly Air Force Base.

Failures of asphalt pavement between the concrete runway ends during this same period, and the phenomenon of aircraft "porpoising," led to the selection of concrete in this area on an interim basis, and to the hearings of this committee in 1957.

These 1957 hearings in turn led to the Columbus test. Here, again, asphalt failed to provide a smooth, hard surface acceptable for heavy bomber operations—a failure which prompted both General Wilson and Mr. Ferry to suggest before this committee on Tuesday of this week a strip of concrete down the centerline of the runway.

During this same period other asphalt runways have failed at civil and military airfields. The Navy has reported several examples, and the Strategic Air Command additional ones. At least three SAC bases are currently faced with operational shutdowns to repair failures of asphalt runway interiors. We do not know of any military airfields, nor have any been reported, where operations have been suspended due to failures of concrete runways.

This is a straight fact: Asphalt pavement performance has not been satisfactory either under normal operations, or in special tests. Concrete has proved to be far superior as an airfield pavement surface. Asphalt cannot take it. Concrete can and does take it.

FUNCTIONS AND REQUIREMENTS OF AIRFIELD RUNWAYS

Thus far, we have reviewed the deficiencies and failures of asphalt paving which resulted in the more widespread use of concrete, and which led to the Kelly test and to the later test at Columbus, Miss.

The test at Columbus and the problem before this committee in these hearings concerns pavement for airfield runways. It is important to consider exactly what requirements must be met by an airfield runway.

FUNCTIONS OF RUNWAY

One of the clearest statements ever presented on the functions of a runway was delivered at the Sixth Annual Air Safety Forum of the Air Line Pilots Association in March of 1957, by Capt. L. Homer Mouden, of Braniff Airways. We would like to quote in part from Mr. Mouden's statement:

> Basically a runway accomplishes three functions for an airplane. It must provide:
> (1) An area for accelerating to takeoff speed;
> (2) A stopping area if the takeoff is not completed; and
> (3) An area suitable for landing and successfully stopping the airplane at the end of its flight.

REQUIREMENTS OF RUNWAY

> For a runway area to permit rapid acceleration to takeoff speed, it must be hard, smooth * * *
> In providing for the landing phases of flight, the runway must be capable of being seen, supporting the airplane upon landing, and providing for successful controlling and stopping of the airplane. This then, requires that it be constructed of a material with a conspicuous surface * * * and provide the maximum braking coefficient—landings during low ceiling and visibility conditions are usually made on wet runways. Many runways are extremely difficult to see when wet during the approach and landing. Many have been found to be slippery when wet. Irregularities, chuckholes, and nutations have contributed to their failure to provide adequate braking coefficients.[1]

PAVEMENT DEFICIENCIES

Smoothness, hardness and good braking characteristics in all weather are keywords. Extensive investigations and pilot interviews have been conducted in an attempt to determine more exactly requirements for surface smoothness of airfield pavements. In reporting on this, Col. Edwin M. Eads of the United States Air Force, in an article appearing in the Military Engineer Magazine, March-April 1958, had this to say:

> The consensus seemed to be simply that airfield pavements should be as smooth as they can be constructed.
> Although not adopted as official criteria, the Air Force now requires the construction of airfield pavements which come close to meeting this requirement. This goal has been achieved through the use of portland cement concrete with sawed construction joints and exacting pavement-grade control criteria * * *.
> Rough pavement results from undulations, ruts, joint drops, horizontal displacements, and erosion.
> Rutting of asphaltic concrete surfaces along the centerline of runways and taxiways is * * * caused by repetition of heavy loads * * *. Rutting is characterized by elevated ridges along the side, and the appearance of "alligator" cracking in the surface course.
> Vertical drops * * * occur * * * where traffic repeatedly crosses the joint between asphalt and concrete pavements. Such drops are characterized by subsidence of the surface of the asphalt pavement adjacent to the concrete.
> Horizontal displacement of asphalt pavement occurs where there has been repeated use of brakes on the same area.

A reprint of this article is included with this testimony and we ask that with your permission it be included as exhibit 1 of this testimony and made a part of the proceedings.

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[1] Runway Operational Requirements for Performance, by Capt. L. Homer Mouden, Braniff Airways, before Sixth Annual Air Safety Forum, Air Line Pilots Association (March 1957).

(Exhibit 1 referred to is as follows:)

HOW SMOOTH IS SMOOTH?

By Edwin M. Eads, Colonel, United States Air Force

In extensive investigations which have been conducted in an attempt to determine surface smoothness requirements for aircraft pavements, many jet bomber pilots have been interviewed. Naturally, most of the pilots when asked how smooth the pavements should be were unable to answer the questions in engineering terms. The pilots were only able to state whether or not they considered certain pavements to be smooth enough or too rough. The consensus seemed to be simply that airfield pavements should be as smooth as they can be constructed.

Although not adopted as official criteria, the Air Force now requires the construction of airfield pavements which come close to meeting this requirement. This goal has been achieved through the use of portland cement concrete with sawed construction joints and exacting pavement-grade control criteria. These criteria require that all aircraft pavements be constructed with not more than ±0.04-inch variance from designed grade and that its surface be of such smoothness as to deviate not more than one-eighth inch from a true 10-foot straightedge placed on the pavement in any direction at any location.

Jet bombers are equipped with extremely high pressure tires to support great weights on a very small pavement area. In the operation of these aircraft it was observed that existing pavements were not sufficiently smooth for an allowable degree of safety during takeoff, landing, and taxiing.

Rough taxiways caused violent lateral and vertical motion of the aircraft and unusual noises (tin canning) within the aircraft. The inability of the aircraft commander to determine the cause of these motions and noises has, in many instances, caused him to stop operations so that the aircraft could be given a complete ground check. Such interruptions waste time and money, interfere with training, and could be the means of preventing aircraft from participating in actual combat missions.

In takeoff and landing operations rough runways set up violent motion, particularly a "porpoising" action which subjects the pilot to an extremely rough ride, mentally and physically distracting him and creating an unsafe condition. These violent motions cause damage to the aircraft and equipment.

Rough pavement results from undulations, ruts, joint drops, horizontal displacements, and erosion.

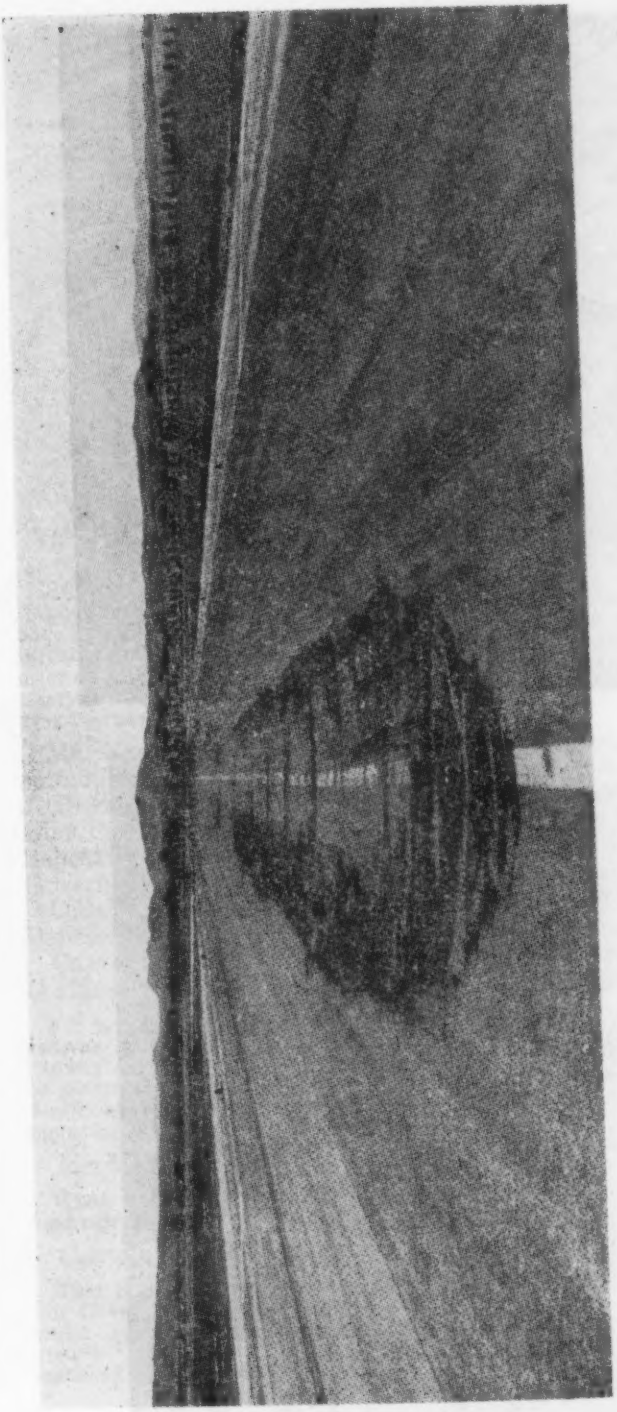
Undulations in asphaltic concrete runways and taxiway surfaces are usually due to inadequate grade-control criteria or they result from subsidence of an area. Subsidence is normally progressive and is aggravated by the increase in the number of impact loads which occur as the size and depth of the affected area increases, even though the gross weights of aircraft remain the same.

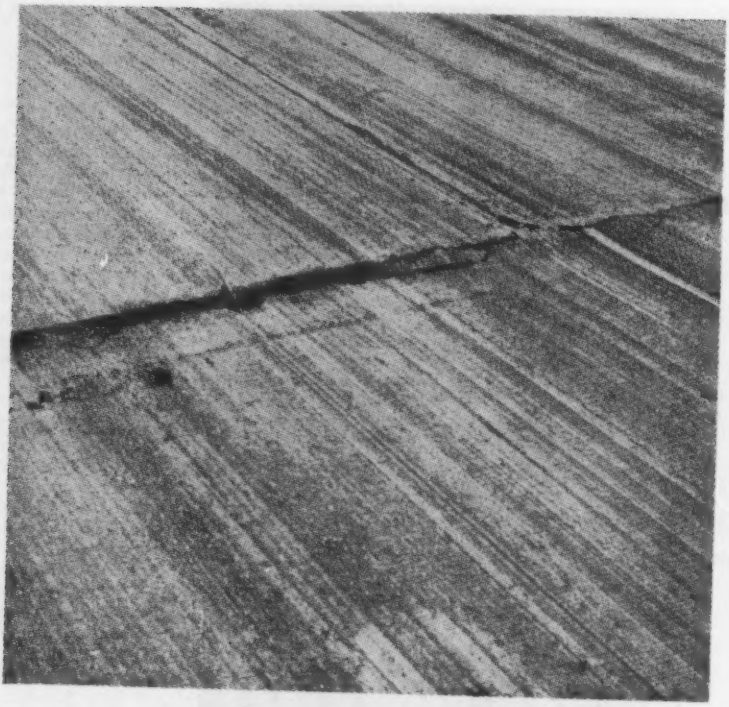
Rutting of asphaltic concrete surfaces along the centerline of runways and taxiways is neither continuous nor of uniform depth. It is caused by repetition of heavy loads. It may be resulting from the downward movement of an entire pavement section, or the plastic or transverse flow of the asphaltic surface course. In some instances, it may occur along the normal wheel tracks of taxiways and runways due to sheer failure of the base course. Rutting is characterized by elevated ridges along the side and the appearance of "alligator" cracking in the surface course.

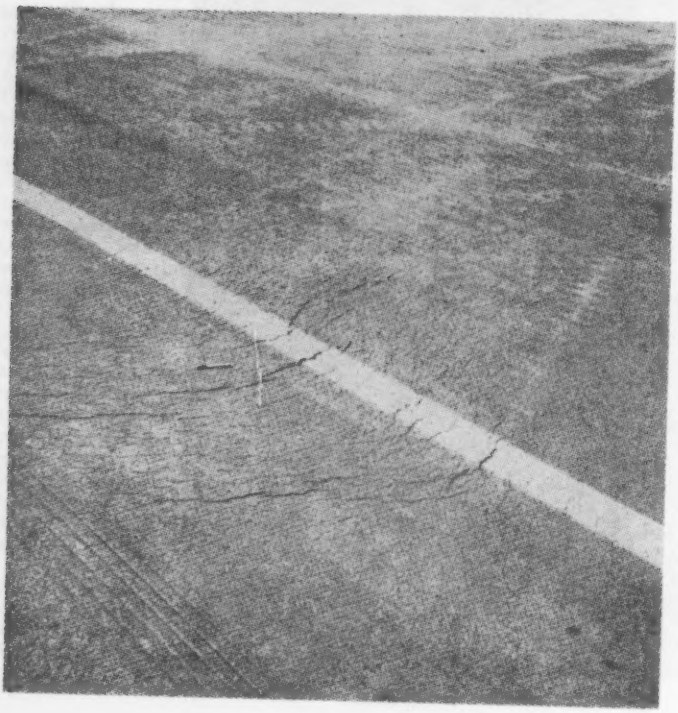
Vertical drops at the butt joints of asphalt and concrete pavements occur at the centerline of taxiways and runways, and at other places where traffic repeatedly crosses the joint between asphalt and concrete pavements. Such drops are characterized by subsidence of the surface of the asphalt pavement adjacent to the concrete.

Horizontal displacement of asphalt pavement occurs where there has been repeated use of brakes on the same area.

Erosion of asphaltic surfaces from jet blasts has occurred in numerous instances on primary pavement areas such as warmup pads, taxiways, and runways. Even slight erosion leaves a rough operating surface, and in some instances total destruction of asphalt pavement has occurred. Eroded areas are often several square feet in size and range up to 6 inches in depth. In addition to creating rough spots, erosion leaves loose particles on the pavement which, if sucked into the jet intake, are damaging to the jet engine.







Concrete aircraft pavements constructed under the stricter smoothness criteria have already been placed under contract at several airbases. Good contractors utilizing available equipment should be capable of constructing pavements which meet the new criteria. In the meantime, the Air Force is continuing with investigations with the hope that eventually they will be able to describe the required smoothness for airfields in engineering terms.

Mr. KENNEDY. If any further evidence is needed of the total unsuitability of asphalt for runways, it is provided in testimony by Capt. J. D. Smith, chairman of the air traffic control committee of the Air Line Pilots Association. This testimony was given before the House Subcommittee on Legal and Monetary Affairs of the Committee on Government Operations on July 31 of this year.

Only a few of Captain Smith's comments under questioning by Representatives Blatnik and Meader will be recounted here.

Captain Smith referred to a recent asphalt runway failure at O'Hare Field, Chicago, in this fashion, and I quote:

* * * For example, because of not technically evaluating the difference in runway usability between a concrete runway and blacktop surface in a new runway at O'Hare (Field), in which much Federal money was spent, 8,000 feet of that runway will now be overlaid with concrete in order to make it suitable for jet age operations, even though this runway has been in use for only a little more than a year.

Mr. Meader asked:

What was wrong there? Should they not have used asphalt or blacktop on that runway expected to be used by jets?

Captain Smith replied:

That is what they did use, and it did not hold up, sir. * * * To go and permit Government money to go into an 8,000-foot runway to do a job for them which you know will not meet the criteria is rather questionable, in our view * * * CAA and the city of Chicago were clearly advised not to put this material on this runway by us. We told them it would not hold up.

After further questioning, Captain Smith said, and we quote:

As far as we are concerned, asphalt should just be outlawed (from Federal Role in Aviation, transcript of July 31, 1958, testimony and hearings of the Committee on Government Operations, Subcommittee on Legal and Monetary Affairs, pp. 748, 749, and 756).

That is a strong statement, particularly important since it was expressed by a committee chairman of the Air Line Pilots Association.

A reprint from the Chicago Daily News reporting the costly error at O'Hare Field, Chicago, is included with this testimony. We request that it be included as exhibit 2 and be made a part of the proceedings.

(Exhibit 2 is as follows:)

O'HARE FIELD BONER TAKES COSTLY TURN—REPAVING OF ASPHALT RUNWAY MAY BE $1 MILLION HIGHER

(By Paul Gapp)

A decision to build an O'Hare Field runway of asphalt has turned out to be a costly engineering blunder, the Daily News learned Wednesday.

It will now cost more—perhaps $1 million more—to put a concrete top on the asphalt strip than it would have to build the original runway of concrete.

The 8,000-foot northwest-southeast runway was built of asphalt at a cost of $1,319,602 in 1956.

It would have cost about $700,000 more to build it with concrete at that time, bid records show.

But the new concrete topping for which bids are now sought will cost far more than the total of these two figures.

A source close to the project said it may be more than $1 million more.

O'Hare manager Ralph Heinze said the asphalt runway was "not engineered" to withstand the 146,000-pound weight of some big commercial airliners now using it.

Other airport sources said water often stands on parts of the strip because of improper drainage. Portions of the runway have developed waviness, they said.

Air Line Pilots Association spokesmen pleaded that concrete be used when the strip was planned in 1955.

Asphalt, they said, is slippery even in fair weather and has a low visibility factor at night.

Others point out that asphalt would not stand up under the weight and engine blast of jet airliners, which will start using the field late this year.

The late Ralph H. Burke, then city airport consultant, argued that the Federal Government would not share the cost of the extra $700,000, but would pay half the cost of an asphalt runway.

Rock Road Construction Co., of Chicago, built the original landing strip.

Funds for the new concrete top will come from a $1-million grant made available by Governor Stratton.

William Nanini, Rock Road president, blamed lack of adequate drainage for breaks in the asphalt.

"We pointed out that very little drainage was provided," he said. "But it wasn't our responsibility to design the job. We followed the city's specifications."

Nanini said the runway was designed so a layer of asphalt could be added later to handle heavyweight jets. He said the decision to lay concrete on asphalt is almost unprecedented and "gives asphalt a black eye."

Nanini said his firm builds with both asphalt and concrete.

Alderman Nicholas J. Bohling (7th) who originally opposed the use of asphalt, termed the situation "as silly as anything possibly could be."

"Mr. Burke overruled everybody," he said. "Why, I could never understand."

Bids on the concrete topping job and allied improvements at O'Hare will be opened August 26.

ESTABLISHED COMPETENCY OF CONCRETE AIRFIELD PAVEMENT

The competency of concrete for airfield paving has been fully established in experience, and documented within the printed proceedings of this committee by witnesses from the Corps of Engineers, the United States Air Force, the Navy, and by other verbal and written testimony—for example, Airstrip Paving Materials, interim report and hearings before the Subcommittee for Special Investigations of the Committee on Armed Services, House of Representatives, 85th Congress, 1st session (August 14, 1957), Subcommittee Proceedings No. 5, pages 1980, 1981, 2017, and Airstrip Paving Materials, secretarial transcript of hearings before this subcommittee December 2, 1958, page 226.

By contrast, the competency of asphalt for heavy-duty airfield construction has never been established. It was precisely this fact that led to the test at Columbus, Miss.

COMMENTS ON THE TEST AT COLUMBUS AIR FORCE BASE, MISS.

The comments and observations presented are based upon conclusions of engineers from the Portland Cement Association present as observers during the construction and testing phases, and subsequent review and study of the reports and statements prepared by the Corps of Engineers.

ASPHALT PAVEMENT CONSTRUCTION

The asphalt test strip at Columbus failed despite unusually favorable conditions of construction and supervision, and the presence of unusually good natural construction materials.

Since the area in which the base is located produces excellent sand and gravel in commercial quantities, the fill material, composed of sandy and clayey gravel, is far superior to average fill material. It is extremely unlikely that natural fill materials of this excellent quality would be found on site at any other airbase in the country.

Chart No. 1, now on the easel, shows a cross section of the asphalt pavement constructed at Columbus. While the original design of the asphalt pavement at Columbus included a 38-inch pavement, the engineering report points out that this pavement was built on top of a fill of selected material which was locally available at the site. This material was of an extraordinary high quality. It constitutes a fill as described of some 10 feet in depth, beneath the 38 inches of the pavement proper.

By the very engineering definition of a flexible pavement, performance of this entire section of the top 38 inches, down to about here [indicating], acts with the fill material as a pavement proper, and, therefore, from the subgrade below the bottom of this chart to the top of the 8 foot 2 inch pile of rock and materials, this is the flexible pavement that was under test, as compared with a much thinner section that was tested a couple of years ago at Kelly Field.

I call your attention to the fact that as this chart is an exact copy from the Engineers' Report, there are layers of 24 inches, of 18 inches and 18 inches, in the fill, which were laid in separate layers and compacted to great density as the work went along.

The material in the fill constitutes a very fine preparation so that the entire pavement may function together as a single entity. It is drawn from plate 4 of the Corps of Engineers report 3–490, Proof-Test Section Columbus Air Force Base, Corps of Engineers, United States Army, Technical Report No. 3–490 (November 1958) (drawing of plate 4).

Gentlemen, you see here an 8 foot, 2 inch pile of stone.

The asphalt pavement surface is 9 feet above the natural ground. An additional few inches are not shown on this chart, but indicated at the bottom as fill.

If you will bear with us we will describe construction of this pile.

First, a 2-foot thick layer of clayey gravel was placed and compacted to good density.

Then another layer of gravel was placed and compacted to an even greater density. It is 1½ feet thick.

On top of this another 1½ feet of gravel was placed, and compacted to 95 percent of optimum density.

On top of this 5 feet of compacted subgrade there were placed a 6-inch thick layer of clay gravel subbase. This was compacted to 95 percent of density.

There then was placed a 7-inch layer of the same material. This was compacted to 100 percent of density, and rolled with a 60-ton rubber-tired roller.

On top of this mass—now more than 6 feet high—there was placed a subbase of gravel, sand, limestone dust and crushed slag. This also was placed in 2 layers, each of which was compacted to 100 percent density and rolled with the same 60-ton machine previously mentioned.

On top of this 6 foot, 11 inch compacted pile there was placed a crushed aggregate base, blended in a pugmill type mixer. Each of the 2 layers of this 11-inch course was compacted to 100 percent density and rolled with the 60-ton roller.

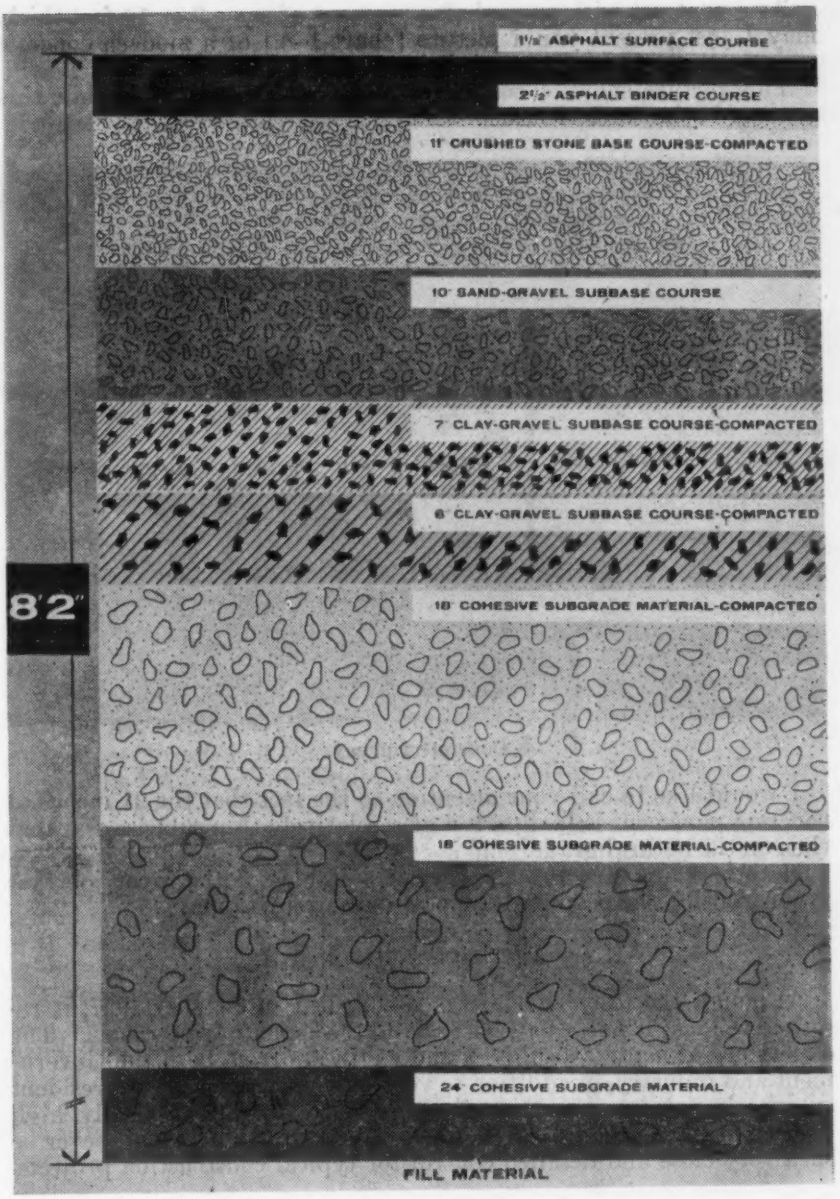
Then, on top of this 7 foot, 10 inch pile there was placed 2½ inches of binder course, consisting of carefully proportioned crushed limestone, crushed and screened chert gravel, limestone screenings, coarse washed sand, fine bank sand and asphalt.

And finally, atop all this there was placed a 1½ inch surface course making a total of 8 feet, 2 inches.

Now, one doesn't have to be an engineer to see that all this compacted pile of stone could not help but benefit the asphalt design. One of the major factors contributing to asphalt failure is its deflection under load. As heavy wheels pass over the surface, the pavement is depressed. If the load is too great, it depresses the soil below, and a pocket, pothole or rut is formed. In this instance, the natural soil is 9 feet below this mass of compacted stone and gravel.

Despite this tremendous thickness of the many carefully controlled, painstakingly constructed layers, the pavement still deformed and failed to meet surface tolerance standards.

Why? It is simply the nature of the material. Asphalt pavement is a flexible pavement. Webster defines a "flexible" material as "that which is easily bent, or which adapts itself readily to change of shape." That is exactly what this pavement surface did; it bent, and it changed shape.


1½" ASPHALT SURFACE COURSE
2½" ASPHALT BINDER COURSE
11" CRUSHED STONE BASE COURSE-COMPACTED
10" SAND-GRAVEL SUBBASE COURSE
7" CLAY-GRAVEL SUBBASE COURSE-COMPACTED
6" CLAY-GRAVEL SUBBASE COURSE-COMPACTED
8'2"
18" COHESIVE SUBGRADE MATERIAL-COMPACTED
18" COHESIVE SUBGRADE MATERIAL-COMPACTED
24" COHESIVE SUBGRADE MATERIAL
FILL MATERIAL

As a contrast with an asphalt pavement of some 9 or 10 feet thick, may I just present you a picture [chart 1–A] of a modern concrete structural pavement, such as is being built today.

This picture shows a concrete runway section that was built this summer in the State of Texas.

Concrete runway.

I would like to call your attention to the fact that the 21 inches of concrete pavement is laid on top of a relatively thin subbase and that then on the natural grade.

Here is a fine structural pavement suitable for the great job that is confronting the people who operate our aircraft today.

ASPHALT CONSTRUCTION TIME

Although the test criteria was established in October 1957, it required the major part of a year to build the asphalt test sections. The experience of many consultants and engineers from both the Government and industry, in addition to very close inspection by the resident engineer's normal inspection force assured an unrealistically high quality in these asphalt test sections. We know there would never be such very close and detailed control for typical construction projects.

ASPHALT-PAVEMENT BITUMEN CONTENT

The bitumen content in asphalt mixes has a critical effect on pavement strength and durability. A reduction of 20 percent below the optimum asphalt content was made in the pavement mix for this test conducted in 24 days. This unprecedented reduction in the amount of asphalt binder, necessary to develop stability under high tire pressures and heavy loads, seriously reduces asphalt-pavement durability.

You will recall that this test occurred during very warm climatic conditions, which are described in the engineering report.

For the warm weather conditions which existed during the test, where approximately 95 percent of the load applications were made at temperatures above 70° F., an asphalt mix with a reduced asphalt content is beneficial. For normal temperatures ranges, such a mix would have developed severe brittleness or lack of flexibility.

The many surface cracks that appeared after "cool weather" (nighttime) testing indicates that the asphalt surface disintegration would be even more severe during actual cool weather traffic common to a large percentage of Air Force bases.

It is probable that the same tests performed under winter conditions would have shown entirely different results. In addition, if these tests had been performed over a period of several years, the factor of durability would have also been tested. Under the conditions established for the Columbus test, asphalt durability was not tested.

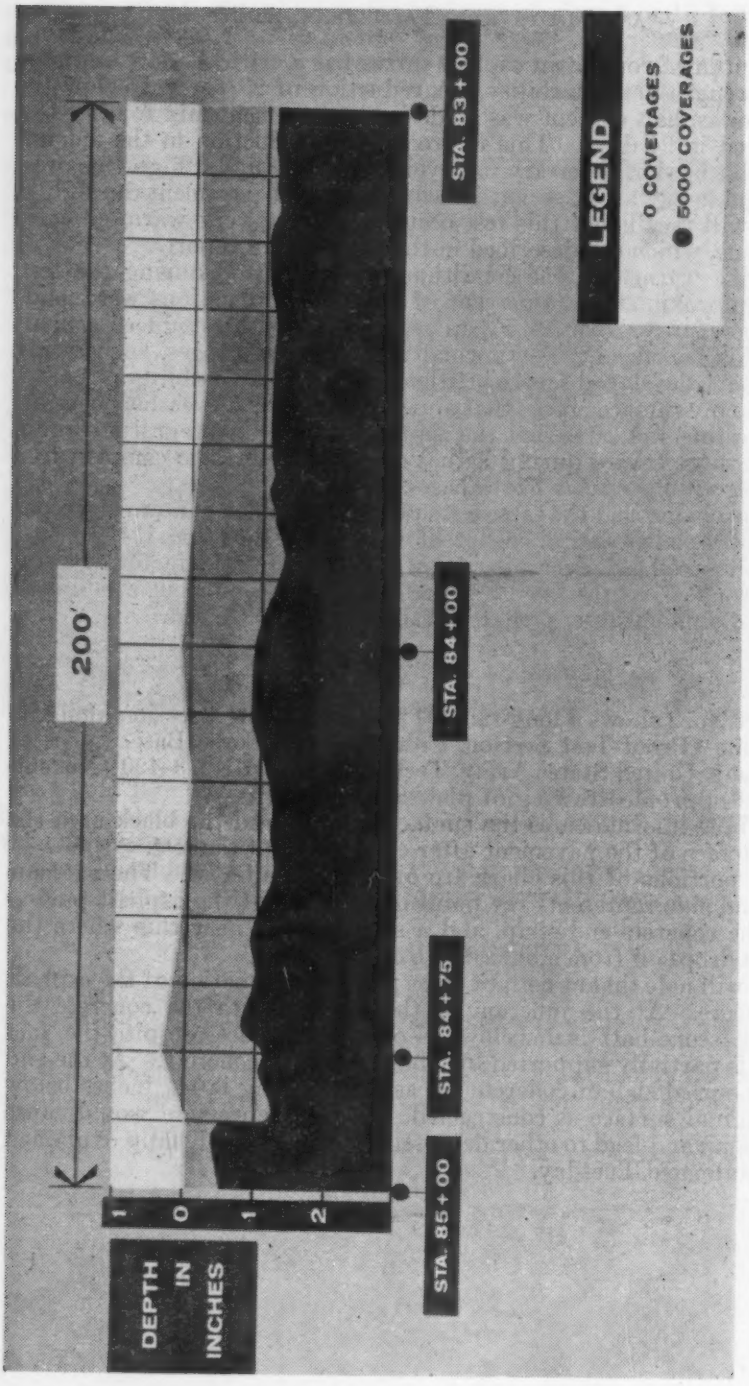
ASPHALT-PAVEMENT TEST OBSERVATIONS

Chart No. 2 shows a longitudinal profile of the test section along its centerline (Proof-Test Section, Columbus Air Force Base, Corps of Engineers, United States Army, Technical Report No. 3–490 (November 1958); profile drawing of plate 20).

The blue line indicates the surface as built and the black area the final surface of the pavement after completion of the test.

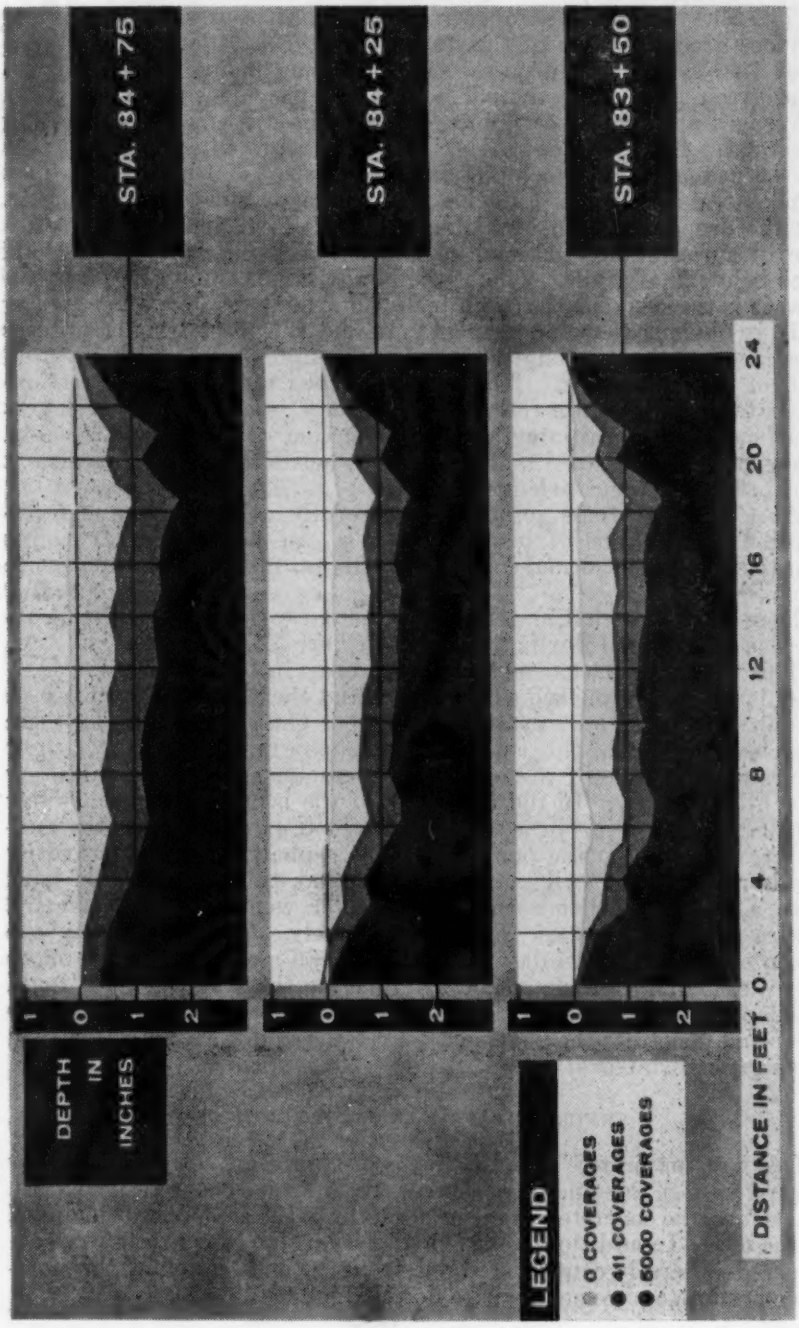
Two portions of this chart are of greatest interest. The extreme left-hand side represents the point of juncture of the asphalt paving with the concrete end strip, and a second point near this where the asphalt drops off from a buried slab of concrete.

You will note that at both of these points deformation of the asphalt was severe. At the junction of the asphalt with the concrete the asphalt is one-half inch below its original surface, despite the fact that it is partially supported by a buried slab of concrete. At the end of this buried slab of concrete the asphalt paving is 1¾ inches below the original surface as constructed. Such a depression would cause porpoising and lead to other depressions, as General Knapp explained in his statement Tuesday.



Asphalt deformation.

Chart No. 3 shows clearly the rutting of this asphalt test runway to a depth as low as 1¾ inches below original surface grade. (Proof-



Asphalt rutting.

Test Section, Columbus Air Force Base, Corps of Engineers, United States Army, Technical Report No. 3–490 (November 1958); profile drawing of plate 15.)

The blue lines on this transverse profile chart represent the original surface grade at three of the stations established along the test section for observation purposes. This was the surface as constructed. The green lines show the surface of the pavement after only 411 coverages at these three points. Notice the settlement and rutting after these few coverages. The black area represents the final grade of the pavement after completion of the test—5,000 coverages. This black area averages 1¼ inches below the original surface grade. At the deepest portion of the ruts, from 9 to 18 inches wide, there are instances where the surface is from five-sixteenths to one-half inch below final grade. This is too low; the maximum allowable tolerance is three-sixteenths of an inch below final grade.

It is obvious that the deepest ruts and the most serious failures occurred at the two longitudinal construction joints which are well within the test lane. Although previous testimony and test reports tend to minimize the failures at these joints, the fact remains that such joints are integral to construction of asphalt pavements. They occur at 10 to 12 foot intervals across the entire pavement width, and for its entire length.

At Columbus, these joints were carefully constructed under exceptional conditions of inspection. We can conclude that joints constructed under normal conditions will also fail, and probably more seriously.

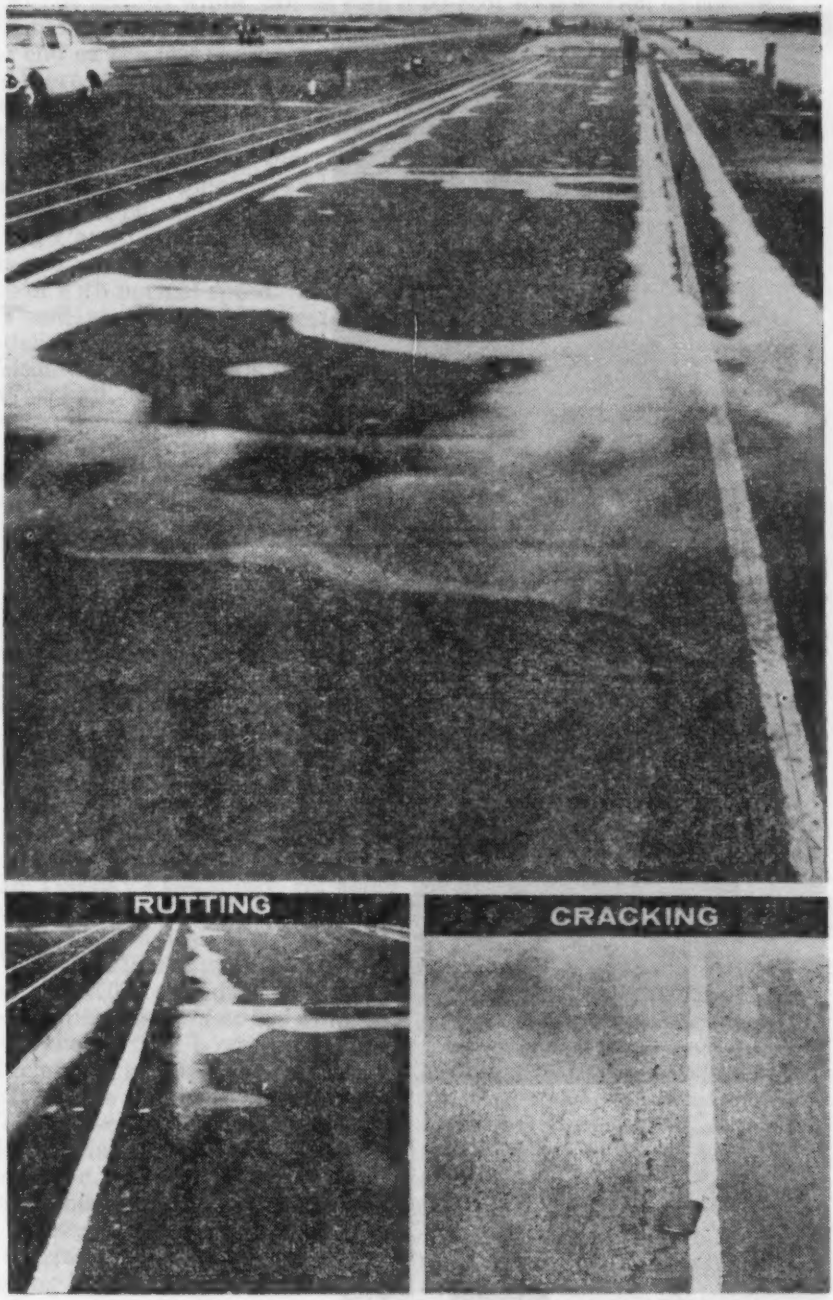
Here you see actual, unretouched photographs of the asphalt surface as it appeared during the test. (Chart No. 4.)

This tells better than a thousand words just what happened.

This is an unretouched photograph, and the water that you see in the picture on the left is standing in ruts. On the upper right, there is a close-up view of this rutting. The photograph at the lower right shows one example of the intermittent cracking that occurred along the entire runway. In the foregoing of the large photograph water can be seen standing in a depression which extends across the runway transversely at the point where the asphalt is not supported by the buried slab—I call your attention that this pavement is built with a crown, so that normally the water would run off laterally. Notice other patches of water, transversely. These cracks in the photo occurred in a 24-day test and you can see that they are more than just hairline cracks. You can imagine the cracking that would develop in this brittle mix during cold weather—allowing water to enter and penetrate the pavement. Freezing and thawing would then cause rapid disintegration.

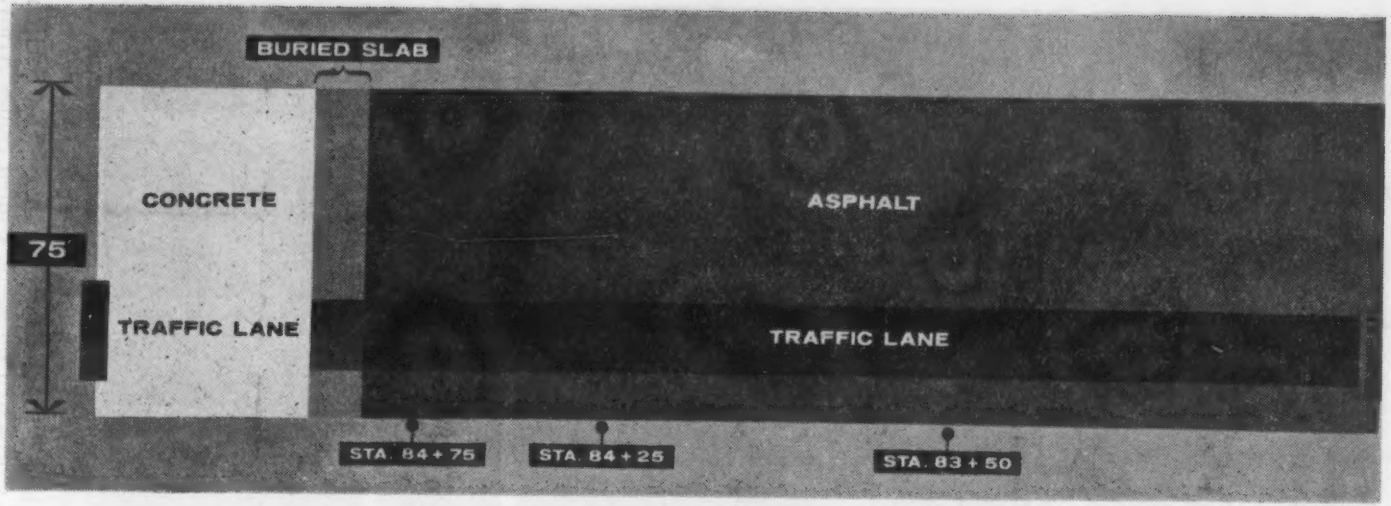
CONCRETE PAVEMENT CONSTRUCTION

In its report on this test, the Corps of Engineers stated that it was desired to test the juncture between asphalt and concrete pavement. Therefore, the concrete pavement adjacent to the asphalt was included in the test. In addition, a buried transition slab of concrete was constructed—literally cantilevered out from the end section of this completed concrete pavement, with a doweled joint.



Early failures.

Chart No. 5 shows the plan of the test section (Proof-Test Section Columbus Air Force Base, Corps of Engineers, United States Army, Technical Report No. 3–490, November 1958); drawing of plate 2).



Layout of test section.

At the left, in white, can be seen a 50-foot long section of concrete, and next to this in gray a 12-foot long buried slab. The concrete at the end of the test section was completed on November 11, 1957, and sat there through the winer and through the spring rains early this year. In July 1958, the subbase next to the concrete slab was cut back, and the buried concrete slab was constructed. It was not until the 25th of August 1958, that the asphalt section was completed—9 months after the concrete, and just 10 days before the test.

It cannot be emphasized too strongly that the concrete was not under test at Columbus. Itw as built using normal construction methods and normal concrete. There was nothing fancy about it. It was put in with normal speed.

Tuesday's testimony indicated that much of the subbase is the same under concrete as under the asphalt. This is true. But, as General Wilson pointed out, this section of the runway was initially designed for asphalt. While fill was necessary for both materials, the base courses definitely were not. Practically all of the base material was in place when a design change was made to use concrete. Although the concrete is on these very deep base courses, required for asphalt, they would not be necessary for concrete in normal construction practice. And they were not, as the photograph showed, of the Texas runway.

CONCRETE PAVEMENT PERFORMANCE

All of the maneuvering of the test vehicle on the test strip was done on the concrete end section, subjecting it to grinding and twisting motions as well as straight-rolling wheel applications. The rear heavy wheels were run up on the bumper on the concrete and allowed to drop on the concrete. This impact of the heavy gear plus maneuvering was not duplicated on the asphalt. The asphalt was the surface to be tested, but the severest traffic took place on the concrete.

SUMMARY OF COMMENTS

In Tuesday's testimony, reference was made to the "normal" B–52 traffic duplicated in the Columbus test. In fact, this test cannot be regarded as "normal."

Was the 212,000 pound load normal for a B–52 gear that carries a load of 265,000 pounds? Was the 4 miles per hour speed normal for a B–52 which takes off at 200 miles per hour? Did the test vehicle duplicate the vertical bouncing action of an actual B–52? Did the test vehicle duplicate the normal braking action and turning of B–52 aircraft? The answer to all questions is "No."

These so-called normal conditions were objected to in a letter from this association to General Wilson of the Corps of Engineers, on November 15, 1957 (letter from James D. Piper, vice president for promotion, Portland Cement Association, to Maj. Gen. Walter K. Wilson, Jr., Deputy Chief of Engineers for Construction, Corps of Engineers, date of November 15, 1957; Airstrip Paving Materials—hearing before the Subcommittee for Special Investigations, part II, p. 2956), as were the abnormal site conditions present at Columbus Air Force Base.

General Wilson in his statement Tuesday indicated that the Columbus test did not provide an answer to the question of resistance of the

asphalt to aging and weathering, and that the mix design used was potentially less durable than the richer paving mixes used in the past. He went on to say that if the older mixes are durable for a period of 20 years, the newer mixes will be durable for 17 or 18 years. Mr. Ferry said, and I quote from page 774 of the transcript—

> * * * We cannot be sure that the degree of reduced durability of the newer mixes will be in the order of only 2 or 3 years.

We doubt that any asphalt pavements are in service at military bases today which have a 20-year life. We seriously doubt that a mix with reduced bitumen content would approach this figure. The Navy report of May 1958 shows that 21 of 28 stations required resealing or resurfacing of asphalt runways in from 5 to 8 years. Reduction in asphalt content of the magnitude made at Columbus will reduce durability even further—particularly in cold climates where mixes lose their durability and become stiff and brittle.

General Wilson's prepared statement of last Tuesday, stated in conclusion No. 1 that—

> Considering normal B–52 operations only, we have concluded that the tests at Columbus Air Force Base demonstrated the validity of the design and construction procedures developed by the Corps of Engineers for heavy load flexible pavement.

We cannot agree. This controlled laboratory type test was not normal. Yet even under the most highly favorable conditions, the asphalt section failed to meet required surface tolerances.

Conclusion No. 5 ignores the severe ruts at the longitudinal construction joints and states that—

> The surface smoothness within the traffic lane itself after completion of the test complied essentially with the smoothness tolerance allowed during construction.

Report 3–490 states definitely that the greatest amount of settlement took place at the two longitudinal construction joints. Both are within the traffic lane.

The basic question of the Columbus test is: When the coverages were completed did the asphalt pavement meet operational surface tolerances? You know the answer: Asphalt did not.

OPERATIONAL NEED FOR CONCRETE RUNWAYS

The critical need for runways constructed of concrete has been emphasized by all civil and military groups directly concerned with the operation of modern heavy aircraft. These groups include the United States Air Force, the United States Navy, and the Air Line Pilots Association. Their primary duty is the operation of aircraft, and they are interested in pavement types only as they affect the safety and efficiency of operations. The overwhelming preference for one type, concrete, over another, asphalt, has developed from years of experience. There is no substitute for this experience.

THE EFFECTS OF HEAVY AIRCRAFT UPON AIRFIELD PAVEMENTS

Modern heavy aircraft, most particularly jet aircraft, can damage asphalt pavement very rapidly. Reports of failure of asphalt at heavy-duty military and civil airfields are increasing. Deteriora-

tion begins in the form of depressions and irregularities in the asphalt runway surface. With each subsequent passage of the aircraft, bouncing on its springy shock absorbers, the depression is deepened until a succession of hazardous potholes is developed. Eventually operations must be transferred to another base until repairs of the asphalt can be made.

These depressions and irregularities are caused by a number of characteristics of modern heavy aircraft.

Failure of asphalt pavement is accelerated by the heat and high velocity of the jet engine blast. The pavement is softened or, in extreme cases, the asphalt binder is liquefied and the surface is eroded by the jet blast or rutted by rolling wheels. From such damage further deterioration is rapid.

Jet fuel, frequently and normally vented on the runway, dissolves the asphalt binder, providing another starting point for spreading deterioration of the runway.

Runway damage from heat and blast of jet engines is now familiar.

However, new and much larger engines now going into use will make such damage even more severe and frequent. These new engines, many equipped with afterburners, make economical operation from any asphalt runway virtually impossible, if any reasonable pavement life is anticipated.

During the 1957 hearings, the Corps of Engineers and the Air Force mentioned a probable future requirement of 325,000-pound gear load on tires inflated to above 300 pounds per square inch (Airstrip Paving Materials, interim report and hearings before the Subcommittee for Special Investigations of the Committee on Armed Services, House of Representatives, 85th Cong., 1st sess. (August 14, 1957), subcommittee proceedings No. 5, p. 1984).

A test is now being conducted with this load on concrete pavement at the Corps of Engineers' Rigid Pavement Laboratory near Cincinnati, Ohio.

I am not sure that that has been called to the attention of the committee.

Mr. COURTNEY. It is in the knowledge of the committee, I assure you, Mr. Kennedy.

Mr. KENNEDY. Thank you, sir.

EFFECTS OF DEFICIENT PAVEMENT ON HIGH-PERFORMANCE AIRCRAFT

The structural failures that have recently affected the B–47 fleet have been discussed in unclassified publications during the past several months. These failures were caused by fatigue of the metal structure of the aircraft. Fatigue of this nature is caused by repeated flexing of the aircraft's structure as loads are applied by aerial turbulence in flight or by loads which are created when the aircraft rolls over rough runways or taxi strips.

Aircraft engineers do not agree on what percent of the structural troubles of these planes should be charged to rough runways. However, there is no disagreement that at least a portion of such trouble must be so charged. The B–47 fleet represents an investment of over $8 billion, and the investment in B–52 aircraft is great and growing.

If even 5 percent of these planes are jeopardized by operations from rough runways, any possible saving in first cost of pavement is certainly a false economy.

THE EFFECT OF SURFACE CHARACTERISTICS ON AIRCRAFT OPERATION

Reduction in braking ability on a wet asphalt runway is well known to operators of heavy modern aircraft. Airline pilots and others have reported planes lost or damaged through inability to stop on wet asphalt runways.

Asphalt pavement when softened by hot summer temperatures offers greater rolling resistance to the acceleration of heavy aircraft than does concrete. This increased resistance results in longer takeoff runs, a serious factor in modern heavy jet-propelled aircraft. It has been reported, from medium bomber bases, that the tires have cut ruts more than an inch deep in the asphalt.

Longer stopping distance and longer takeoff run on asphalt have been confirmed by the Navy report of May 1958, which is a part of the record of these hearings (Report on Rigid and Flexible Type Pavements for Naval and Marine Corps Air Station, Bureau of Yards and Docks, May 1958).

OBJECTIONS TO A HYBRID PAVEMENT RUNWAY DESIGN

Recent statements before this commitee indicate there is under consideration a runway pattern consisting of a relatively narrow concrete strip down the runway centerline with an asphalt on each side to complete the runway width. Such a pattern would provide another in a long series of unsuccessful experiments attempting to join these two materials without objectionable roughness at their juncture. As repeatedly stated, concrete is rigid, asphalt is flexible. Differential settlement is bound to occur with materials having such radically different characteristics. The result, a rough and uneven longitudinal joint, hazardous to aircraft operation.

When the difference in elevation is recognized, repairs will be undertaken. But this will not be a $200 or $1,000 repair job. To bring the asphalt back up to grade at its junction with the concrete, the entire asphalt surface will have to be overlaid. It is quite possible that before the need for such repairs becomes obvious to the operating people aircraft will be damaged or destroyed and airmen injured or killed.

Even without a difference in elevation, the difference in surface texture of the two materials will create an operational hazard. Differences in rolling resistance and in frictional coefficients of the two surfaces will make the control of aircraft more difficult. The situation might be likened to driving on a highway at exceptionally high speed with 2 wheels of the automobile on the pavement, and the other 2 on the shoulder. Even today, the problem of controlling modern aircraft directionally during the takeoff and landing roll is one of the most difficult the pilot has to face. To complicate this further seems unwise, to say the least.

The hybrid design concept proposed, a runway built of two different materials, has built-in operational difficulties. It is a concept alien to the basic requirements of a runway.

ECONOMY OF AIRFIELD PAVEMENT SELECTION

In past testimony, this committee has indicated a basic concern with pavement economics, provided that one pavement can be shown to be as good as the other in terms of durability, safety, good performance, and overall operational desirability. This makes good sense.

Testimony before this committee has established that the one pavement, asphalt, is not as good as the other, concrete. General Wilson, Mr. Ferry, General Knapp, Admiral Peltier, and Air Force officers who have appeared before this committee in past hearings have indicated that if first cost were not a consideration, they would select concrete for airfield runways.

The cost of construction is not the only cost consideration in the selection of airfield paving materials. Economics of pavement life, pavement maintenance, aircraft wear and tear, and interruptions to operations far outweigh any relatively small initial differential that might exist in pavement costs for the interior portion of our runways.

Certainly consideration should be given to combat effectiveness. Types of missiles, aircraft, submarines, and even rifles are not selected on the basis of first cost alone but on their performance. That is the criteria. If it were not, we might still be depending upon Civil War weapons for our defense.

COMPETITIVE BIDDING

During the course of these hearings much has been said about whether concrete and asphalt are competitive materials from a bidding standpoint. This subject needs clarification. The two materials may be competitive pricewise but certainly not on a performance basis.

Competitive bidding, as used in connection with contract construction, refers to prospective contractors who submit bid quotations based on specifications requiring a single type material which will be used to build a facility that meets specified standards of construction. From this standpoint, two completely dissimilar materials cannot be considered competitive since, obviously, they cannot be built under the same specifications. Bidding based on specifications requiring one type of pavement is truly competitive, since several contractors bid on one set of specifications.

Alternate bidding is something else again. It refers to two sets of specifications, one for the item actually desired and the second for an item recognized as inferior but which may have to be accepted on the basis of first cost. This type of action better describes the competitive position of concrete and asphalt.

THE COST OF TAKING ALTERNATE BIDS

It is a well-known engineering fact that engineering costs are more than doubled on alternate bids. Grading is different, material which must be tested is different, and two complete sets of plans and specifications must be prepared. In addition, if both types of pavement are included at 1 site, 2 sets of inspectors must be provided at both the batch plants and the paving and grading locations. These additional engineering costs are well known to highway departments who do not

follow this practice. The cost to contractors who bid on both types is also higher, since they must calculate their bids for two different sets of plans and specifications. This extra cost of double preparation is included in the contractors' bids on both pavement types.

SUMMARY AND CONCLUSION

Let us refer again to chart No. 4, while these points are briefly reconsidered.

This pavement is not resistant to fuel spillage. Concrete is.

This pavement is not resistant to jet blast. Concrete is.

This pavement cannot support heavy wheel loads and high tire pressures and still meet surface tolerance. Concrete can.

This pavement does not have a clean, visible, skid-resistant, even surface. Concrete does.

Asphalt meets none of these basic requirements of an acceptable airfield runway. Can it then be seriously considered a suitable pavement from which our pilots must operate heavy jet aircraft?

You have heard testimony describing the inherent hazards and deficiencies of a blacktop runway with a narrow strip of concrete down the middle. This would be a dangerous compromise in view of the record of unsuccessful experiments in attempting to join the two materials.

Throughout our testimony we have documented the superiority of concrete with statements by the pilots and the agencies who operate aircraft, military and civilian. In the same manner, we have documented the deficiencies of asphalt with statements by these same agencies and personnel.

Neither the Navy, the Air Force, the Strategic Air Command, nor airline pilots, have advocated the use of asphalt for airfield runways.

The men who will be affected most by your decision have no profit motives and no vested interests. These men are required to operate immensely expensive and intricate aircraft which demand the ultimate in performance and judgment, and which permit no error in either of these. They are only asking for a type of pavement which actually experience has taught them will make their difficult job, the defense of this country, safer for their planes and for themselves and their crew.

Upward of 60 percent of all aircraft accidents occur during takeoff and landing on runways. Within a 3-day period recently there were 2 fatal crashes of aircraft at an eastern Air Force base. A total of nine men, pilots and crew, lost their lives in these accidents which occurred during takeoff.

Before a bomber crew flies a mission with a B–52, something like 3 hours are spent in checking the aircraft to make certain that every component is in readiness and that any deficiency is corrected that might affect safe and dependable performance. Unfortunately, these airmen cannot correct deficiencies of the pavements from which they must operate.

I now turn after completing the review of the engineering analysis to the summary prepared for this committee.

Gentlemen, having reviewed with you the engineering analysis and conclusions relating to the recent failure of the asphalt-flexible pave-

ment test at Columbus Air Force Base, arrived at by the able and experienced staff of the Portland Cement Association, I wish now to summarize with candor and frankness the facts relating to the matter which the subcommittee has been investigating periodically for 4 years.

ADVANCING REQUIREMENTS OF MILITARY JETS

During the time period under discussion, the past 4 years, advances in the sciences relating to national security have been greater than the sum of developments in the entire period of recorded history. While atomic-powered aircraft, guided missiles, and satellites occupy our thoughts for future defense, the cold grim reality is that, for the foreseeable future, manned aircraft operating from land bases constitute the principal deterent against the Communist threat.

In this 4-year period the Air Force has advanced from B–47 jet aircraft to B–52's and is approaching the use of the heavier and more powerful B–70. These aircraft are tremendously costly—each one is a delicate scientific instrument operated by skillful men trained at great cost to the Nation.

The jet age brought critical problems to airbase runways in spillage, heat, and blast, and increasing pavement surface damage through higher tire pressures. These entirely new elements quickly focused attention on the attendant problems of engineering design, construction, operation, and maintenance. All this required that pavement in critical areas be constructed only of portland cement concrete, a material susceptible to the principles of structural engineering design, rather than the so-called flexible pavement previously allowed which cannot be so designed.

Parking areas, aprons, warmup pads, taxiways, and increasing lengths of runway ends were progressively added to the critical areas because of jet damage, maintenance problems, and operational requirements.

As these newer aircraft in takeoff and landing required smoother pavements to avoid porpoising or vibration of delicate instruments and control apparatus, construction tolerances for smoothness were increased to $\frac{1}{8}$ inch in 12 feet, longitudinally, and $\frac{1}{8}$ inch in 12 feet transversely.

And during this period they had even advanced to a higher degree of accuracy, but had to be reversed because of construction requirements.

At the recent asphalt test at Columbus Air Force Base, the surface failed to meet these tolerance requirements while under, during, or after testing.

The increasing need for, and use of concrete brought complaints from the petroleum groups who manufacture asphalt and the contractor organizations who specialize in flexible construction. They brought their commercial woes to this committee.

PUBLIC HEARINGS

For the third time your committee is devoting its important hours to hearings resulting from these complaints. The astonishing proposals now before the committee present the grave danger to our

national security that hasty conclusions may be drawn by the committee because its sessions must conclude before year end.

In the 1954 hearings the Portland Cement Association with its unusual facilities concisely and carefully presented to the committee in words and graphic art the effect of modern jet aircraft on pavements and the engineering requirements for proper design of such pavements.

In the 1957 hearings the association again, with realization of the committee's need for authentic facts, presented the effect of the pavement on the aircraft, its pilot, and their safety.

Both of these statements constitute historic documents in engineering annals. In the current situation may I strongly recommend them to you for review. They are more pertinent now than ever before.

Since, through error, they were not included in full in the record of previous hearings, may I now offer them for inclusion in the record of current hearings. At a later date I would like to present to each committee member a complete set of Portland Cement Association testimony with charts shown in full color not reproducible in the record.

PAVEMENT TESTS

During these 4 years two accelerated tests of pavement performance under heavy loads were conducted. Designed to partially stimulate operation conditions, they did not expose the pavement to any of the special hazards of the aircraft or their jet engines since only a mock undercarriage with a dead load was used. The first took place in 1956 at Kelly Air Force Base, Tex.; the second at Columbus Air Force Base, Miss., in 1958.

KELLY TEST

Although asphalt interests publicly predicted a vindication of flexible pavement at Kelly, it failed dismally, as you will remember.

Sections of concrete and asphalt pavements constructed in a taxiway were simultaneously tested. Thirty thousand coverages of the test vehicle were expected to pass over both sections. At 3,000 coverages the asphalt was in serious distress while the concrete was in excellent condition. At 9,000 coverages the test was charitably stopped since asphalt had failed. No damage had occurred on the concrete pavement. For the record, the flexible pavement was 52 inches thick and the concrete 20 inches.

Asphalt alibis and tears were spread all over the committee record, but you must realize that in many ways the Kelly test had more engineering validity than the Columbus test. I suggest a further review of the test results which are in your record.

Nevertheless, diversionary tactics and confusing evidence impelled the committee toward the end of the 1957 hearings to ask the Corps of Engineers if it was humanly possible to construct a flexible pavement capable of meeting the Air Force's exacting tolerance requirements under heavy wheel loads of the B–52.

The Corps of Engineers undertook this effort at Columbus, Miss., and the pavement failed. If you will examine Technical Report No. 3–490, you will find there, and elsewhere in this week's testimony, this language: * * * the surface smoothness * * * was * * * within the * * * tolerances * * *, except that* * *," or, "complied

essentially with surfaced tolerances." It is these exceptions that constitute failure.

Also let us note that included in this test are none of the operational effects of the jet engine and the flying characteristics of the plane on the pavement, spillage, heat, blast, dynamic impact, and braking. It does not answer other paramount questions of safety for plane and pilot, except the unsafe condition caused by rutting, cracking, and shoving.

It answers none of the questions posed by freezing weather in other latitudes and none of those raised by engineers about the loss of durability over a period of time in view of the lean mix adopted.

The corps and the Air Force have reported their concern about the durability of the mix.

COLUMBUS TEST

The record of the 1957 hearings and subsequent correspondence made public between Chairman Hébert, the Air Force, and the Corps of Engineers show beyond a shadow of a doubt that the intention of this committee was solely to test asphalt-pavement capability. The record is now further confused by the introduction, by the testing agency, of the admittedly serious problem of ever being able to construct a transition between concrete and flexible pavement at a critical takeoff point 1,000 feet down the runway. This must be a factor in what I have referred to as the astonishing proposal. The proposal abandons the idea of building a flexible pavement in the central portion of the runway, which obviates the necessity of a transverse joint, but introduces a far more hazardous longitudinal joint in the runway itself. You have driven an automobile on a narrow concrete pavement widened with asphalt which quickly settled under the impact of truck wheels riding off the edge of the concrete. Such driving conditions are, indeed, hazardous. Can you imagine the result of such shoulder ruts at the edge of a 75-foot runway on the delicate instruments of a B–52 taking off at 100 or 200 miles per hour, or the porpoising effect on flying stability of the aircraft? Such takeoffs are easily aborted.

The effect is to narrow jet runways to 75 feet and provide wide, dangerous shoulders. Safe? No. A bomber cannot safely fly and land on a narrow 75-foot runway. The outrigger wheels would be off the concrete pavement.

The concrete joint did not fail or deform at Columbus and the concrete provided the maneuvering area for the test truck. These nonoperating torsional stresses might well have caused great distress to a lesser material than concrete and certainly would have had they occurred on the asphalt.

It does so confuse the basic question that I venture to suggest that the committee require the "Technical Report No. 3–490" be carefully rewritten and devoted only to the committee's objective.

ORGANIZATION RELATIONSHIPS OF THE TEST

While the Air Force faces all the operating problems discussed in this summary the engineering and construction activities are carried out by its agent, the Corps of Engineers, under the supervision of the Air Force Department of Installations. The technical guidance of the

Columbus test was placed under the corps' flexible pavement laboratory at Vicksburg. The challenge to these people was one that affected the future programs, growth and budget for the flexible laboratory and indeed individual careers. Their effort was commensurate with the challenge.

A similar concrete paving laboratory is maintained by the corps at Cincinnati. Testimony does not show the extent to which their professional knowledge was utilized.

I do know that although the Portland Cement Association maintains the largest research and development laboratories in the world devoted exclusively to cement and concrete, our role at Columbus is described as that of "sidewalk superintendents." I am one of many of our engineers so listed.

Perhaps a more important matter in these complex Defense Establishment relationships are the operational problems. Such branches of the Air Force as the Strategic Air Command, whose mission is our only bulwark against Communist total war have a far greater stake in this test than the Corps of Engineers.

I respectfully suggest to the committee as I privately suggested to Chairman Hébert many months ago that this investigation cannot be considered complete until you have heard from that great and forthright American, Gen. Curtis LeMay. Military and civil pilots unanimously demand concrete runways for the preservation of their own lives.

Let us consider some aspects of the test itself.

DESIGN

Our testimony has shown concrete and asphalt design problems are not compatible or comparable in any way.

Many definitions of flexible pavement are available. Let me quote one:

> Thus a flexible pavement may be most clearly defined by contrast with the rigid pavement which bridges over inadequate support and localized weakness whereas the flexible pavement structure is designed primarily to develop maximum subgrade support through flexibility. Emphasis is placed on a recognition that the subgrade is the ultimate supporting medium.

As I have said, the design thickness at Kelly for flexible pavement was 52 inches and for concrete, 20 inches. The Corps of Engineers Technical Report No. 3–490 states that for the flexible pavement the design thickness as selected was 38 inches and the concrete cantilever springboard 18 inches.

That is not a valid comparison. The test section was built on a carefully constructed fill, 9 feet thick.

It was built of carefully selected material suitable for compaction, constructed in lifts each rolled with heavy equipment to densities comparable to the upper layers. Thus the so-called subgrade becomes by definition part of the total flexible pavement design thickness.

Where Kelly was 52 inches thick the asphalt at Columbus was 98 inches thick. Would you not expect some improvement in performance?

If you will permit a personal observation from this sidewalk superintendent who visited the site on September 10, I want you to know that a competent engineer at the base quite voluntarily told me that

he had never seen such splendid gravel, sand and other aggregates occurring in nature as at this site. This was the material employed in the flexible base. A commercial gravel plant is located here because of this high quality. Such materials would normally be totally uneconomical for use in the construction of fill material.

Let us move on to the construction of this remarkable test section.

CONSTRUCTION

A major jet airbase was under construction at Columbus when this site was chosen. The contract involves many millions of dollars. The prime contractor constructed the test section.

As a second personal observation, again voluntarily, on September 10 the contractor's principal representative told me in effect that the only thing the test would prove was, that in this minute area of a vast base, with this hand-tailored construction project in this particular latitude and climate, during the days of the test itself with the specific materials found in the locality with the total thickness of flexible pavement, 9 feet, conceivably certain specific conclusions might be drawn, but nothing applicable at any other place or time or condition.

The corps has stated the economic comparison would have little worldwide application.

The Columbus test, even though it failed, cannot be measured by normal standards of engineering design, construction or evaluation.

COST

Gentlemen, what of the cost of this type of construction?

You can never accomplish the construction of the equivalent of the Columbus test section on a full-scale construction project for less than three times the cost of the concrete section chosen as the design equivalent at Columbus. The concrete would not require, of course, the thick flexible base, 9 feet, required at Columbus because of its structural ability to distribute the load over a wide area.

Your records show in 1957 testimony at Kelly where more normal subgrade conditions existed, the asphalt pavement that failed cost $11.70 per square yard compared to $9.90 for the concrete. What did Columbus cost?

CONDUCT OF THE TEST

Procedures of the test itself, such as the maneuvering of the test vehicle on concrete, and methods of measurement and reporting cast further doubt on the validity of the test.

For many decades the common tool used for measuring irregularities of pavement surface has been the straightedge. Usually about 12 or 15 feet long, it gives a simple method of observing deviation from a desired plane surface or gradient. It is a quick check on tolerance requirements.

Let me briefly state that in my visit to the test I asked for a straightedge and was denied the privilege of placing a straightedge on the test section.

Mr. COURTNEY. Were you inhibited?

Mr. KENNEDY. I was inhibited.

My third and last personal curbstone observation is that the Vicksburg staff denied me the privilege of placing a straightedge on the pavement, even though I arrived early in the morning prior to the start of the day's operations. The asphalt appeared to have irregularities at the edges of paving strips. It appeared to be shoving or rutting some distance out in the test area from the transition section. It had obviously settled over its entire area and unevenness existed in many spots where water had previously stood.

I do not think there was a straightedge at the test section. Rather, measurements were taken at intervals using a surveyor's level and vertical scale.

Complete data as to these measurements have not been included in testimony or the engineering reports.

Subsidence and deflection measurements are presented at points on certain selected sections. We would like to examine carefully all recorded measurements.

RESULT

We have shown in previous engineering testimony that on the basis of other testimony presented the surface failed to meet the tolerance standards set by the Air Force and, therefore, the payment failed.

INTERPRETATION OF RESULTS AND CONCLUSIONS BY CORPS

One principal interpretation of results by the corps seems inconsistent with engineering practice.

One recommendation by the corps seems to offer a compromise which is terribly dangerous, uneconomic, and not in the public interest.

The interpretative language previously cited, "* * * the surface smoothness * * * was * * * within the * * * tolerances * * *, except that," must be challenged.

The tolerances were met, or they were not. And they were not.

We have described the hazard to men's lives in the compromise suggested by the conclusions of the corps.

We hope and believe the committee will not accept the proposal without full-scale exhaustive testing on a runway over a period of time of the dangerous longitudinal joint proposed.

The recommendation appears to be based on the failure of the transverse joint to function properly. It can be compared to an automobile passing over a bridge with asphalt and fill settlement on either side of the concrete structural deck, a relatively common situation. These transverse joints are hazardous for an automobile as compared to the high speeds of an aircraft.

Longitudinal joint settlement—the narrow concrete road widened with asphalt comparison—is infinitely more dangerous. One occurs only at specific points, the other on the entire length of road or the runway.

If the conclusion is not based upon the failure of the transverse joint to function properly, then it can be predicated only upon failure of the asphalt pavement—or unsound compromise.

In the 5 minutes remaining of my alloted time, I will read the conclusions of my summary.

The 1958 asphalt pavement—flexible base at Columbus Air Force Base again failed the test.

Only a few more considerations:

The committee is exploring an area which should be left completely to the considered judgment of the scientists and engineers of the Air Force and the Corps of Engineers.

Such testimony has been given by the Navy Bureau of Yards and Docks. It is conclusive and unassailable. Nothing but concrete is good enough for the requirements of the Navy and the Air Force.

Commercial pleas of contractors and purveyors should not enter into these deliberations.

Safety of pilots' lives and the safeguarding of extremely expensive bombers, whose purpose is the defense of our lives, demand the very best.

Almost unlimited funds are given for equipment for our pilots with public approval for the Nation's defense. Should we quibble or endanger these pilots on the vitally essential ground facility requiring smooth and durable payment?

Cost of concrete will be far cheaper than construction and costly repair and costly delay involved in asphalt flexible runways. This is the way to true economy.

In this interest may I strongly urge that the committee impose no further restrictions in this critical hour on the engineering decisions which the military agencies are called upon to make concerning pavement type.

Thank you, Mr. Chairman and gentlemen.

Mr. HÉBERT. Thank you very much, Mr. Kennedy. I gather from your vigorous, gloves-off, no-holds-barred statement, that you have come to the conclusion that the Columbus test was a failure?

Mr. KENNEDY. Yes, sir.

Mr. HÉBERT. And you make that statement in view of the testimony by the Deputy Chief of Engineers, General Wilson, who said it was a success?

Mr. KENNEDY. I make that statement clearly in view of the statements which I have read in his prepared testimony, in view of the statements that appear in General Wilson's statement which is here.

Mr. HÉBERT. All right. I think the committee got the impression that General Wilson said it was a success, and you say flatly it was not a success.

Mr. KENNEDY. I say flatly it was not a success.

Mr. HÉBERT. Now, there are 1 or 2 things I want to clear up definitely in the mind of you and everybody else.

You have made reference several times to the commercial aspect of those who are petitioning the committee. I want you to know and understand well this committee has no interest at all in the commercial aspects of either portland cement or the asphalt industry.

Mr. KENNEDY. That is very clear, sir.

Mr. HÉBERT. We do not carry the bag for either one of you.

Mr. KENNEDY. That is very clear.

Mr. HÉBERT. And if the shoe was on the other foot, would you hestitate to come before the committee to present your case?

Mr. KENNEDY. There are no concrete contractors that testified at any time during the 3 years.

Mr. HÉBERT. Whom do you represent? The cement industry, don't you?

Mr. KENNEDY. I represent the portland cement interests—the manufacturers of portland cement.

Mr. HÉBERT. Well, would it be any different if the manufacturers of asphalt had come in instead of the contractors?

Mr. KENNEDY. No. Let me clarify that point.

Mr. HÉBERT. I think it should be clarified.

Mr. KENNEDY. My whole point is that neither of us should be here. Neither of us should be here. This is an engineering matter. Our arguments should be directed to the Corps of Engineers, the Air Force and the Navy.

Mr. HARDY. Mr. Chairman may I make a comment about that?

Mr. HÉBERT. Yes.

Mr. HARDY. I am disturbed by some of your statements, Mr. Kennedy, actually. I think some of them are of rather dubious propriety. However, I certainly would hate to see the impression left that this committee has undertaken to exercise engineering judgment, and certainly I am not aware of any reason why anybody should make any such assumption as that.

Now, one of the purposes that I think we do have a responsibility for is to try to see that proper engineering judgment is rendered.

I certainly want it clearly indicated that this committee is not trying to interpose its judgment with respect to engineering adequacy, as you have implied, and frankly I think that implication is in very poor taste.

Mr. KENNEDY. I am very happy to stand corrected, sir.

Mr. HÉBERT. Now, I want to ask one other question.

You referred to two recent disasters, aircraft crashes. Where did they take place?

Mr. RAY. May I answer?

Mr. KENNEDY. Yes.

Mr. RAY. Loring Air Force Base in Maine.

Mr. HÉBERT. Loring Air Force Base in Maine.

Mr. RAY. Loring; yes, sir.

Mr. HÉBERT. Was that an asphalt runway?

Mr. RAY. To the best of my knowledge that is an asphalt runway with 1,000 feet of concrete at each end.

Mr. HÉBERT. Was it a pavement failure that caused the crash?

Mr. RAY. All we know is that we have a newspaper clipping that two accidents take place on takeoff within a month. We do not know the nature——

Mr. HÉBERT. But the implication is left in Mr. Kennedy's statement that asphalt caused it.

Mr. RAY. That he didn't say.

Mr. HÉBERT. Of course he didn't say. What he didn't say is what I am talking about. That is what I am trying to find out. I know what he didn't say. I want the facts.

Mr. RAY. Our only implication is that the runways are very critical to proper takeoff.

Mr. HÉBERT. You don't know what caused the crash?

Mr. RAY. We do not know what caused the crash.

Mr. HÉBERT. So the introduction of such an example into this particular testimony has no place, if you don't know the facts. Unless you are able to testify to the facts, we consider the situation between asphalt and cement and that should be the focus of our attention.

So if you don't know what took place—I don't think it proper to bring that in here. I want to clear that up. If asphalt was the cause, it would have been all right with me, if you told me the fact. I hold no brief.

Mr. KENNEDY. The record shows, as the statement indicates, that 60 percent of the aircraft accidents occur on takeoff or landing—in the area of the takeoff or landing.

Mr. HÉBERT. Does it show that 60 percent of the crashes occur on asphalt?

Mr. KENNEDY. I did not make that statement.

Mr. CUNNINGHAM. He didn't make that statement.

Mr. HÉBERT. I am trying to find out what he means.

Mr. KENNEDY. The point, Mr. Chairman, is that the zone of the airport is a very hazardous area and it requires the very best of materials on the runway to protect the aircraft in its takeoff and landing.

Mr. HÉBERT. We admit that, and I think the committee admitted that right from the very beginning. We are talking about the noncritical areas, the places where it is not necessary to use the expensive cement. That is—all I am trying to find out is—these figures when you throw them out, where you say 60 percent of the crashes occur on takeoff, then the next question I ask is, where does it take off, period? Where is the area?

Is the composition concrete, or asphalt, where these crashes occur?

Mr. RAY. Sir, we are trying to show you that the runway is a critical area, and not noncritical. That term "noncritical" came from the hearings in 1954 when they were talking about the effects of fuel spillage and blast. Nothing was brought up in those hearings about the safety of operations.

Now, since that time, airline pilots, Air Force personnel—that is SAC personnel—have brought out the facts that this center portion of the runway is critical to safe operation because of porpoising which develops just prior to takeoff.

Mr. HÉBERT. I do want the record to stand corrected there. From the very beginning the element of safety was brought into all the hearings.

Mr. Cunningham, in particular, pressed that, I think in his questioning throughout the hearings.

Mr. KENNEDY. That is particularly true.

Mr. HÉBERT. The premise of all his questioning was on safety.

Mr. KENNEDY. That is right.

Mr. HÉBERT. So safety has been a factor in consideration before the committee.

Mr. KENNEDY. Mr. Ray referred to the 1954 hearings. In 1957 particularly the hearings were devoted to safety.

Mr. HÉBERT. That is correct.

Do you have any question, Mr. Cunningham?

Mr. CUNNINGHAM. On this airport where the two crashes occurred, what was the paving material? Was it flexible or rigid or what was it?

Mr. RAY. As I say, to the best of my knowledge, it is an asphalt runway with 1,000 feet of concrete on each end.

Mr. CUNNINGHAM. And where was the plane when the accident occurred?

Mr. RAY. That is not clear in the newspaper article. It said the accidents occurred during takeoff, was the reference in the article, in the Chicago Daily Tribune.

Mr. KENNEDY. The records of aircraft accidents are not available to us in the Air Force.

Mr. HÉBERT. I am not going to labor the point, Mr. Cunningham.

Mr. CUNNINGHAM. No. I want to go to something else. I want to say that I appreciate your statement that you shouldn't be here. You should be giving your testimony before the engineers. That strikes me as correct.

Mr. KENNEDY. Thank you.

Mr. CUNNINGHAM. I think it was a very valuable statement, but some of it is over my head because I am not an engineer.

Mr. HÉBERT. If we follow that thought, Mr. Kennedy, I don't believe you would be in court today if you appeared before the engineers, because they disagree with you. Would you accept their decision, then?

Mr. RAY. Sir, the Air Force doesn't disagree with us. In all of their hearings in the very beginning the Air Force have wanted concrete and they have told you in testimony that if costs were no consideration they would build concrete. I think that goes all the way through.

Mr. HÉBERT. It is always refreshing to note the Air Force is economically minded.

Mr. Hardy.

Mr. HARDY. Mr. Chairman, I don't want to pursue this to any extent, but there are several things in Mr. Kennedy's statement that bothered me a little bit.

Certainly insofar as this committee is concerned we don't profess to be engineers and I am not going to attempt to render any engineering decisions.

But the fact that the Air Force wants concrete doesn't necessarily mean that it is either necessary or desirable that all of the paving be concrete. That is the thing that I am trying to reconcile, or trying to cause the agencies which do have a responsibility to reconcile the differences of opinion.

Now, you said you were denied the privilege of using a straightedge at Columbus, I believe.

Mr. KENNEDY. That is correct.

Mr. HARDY. Who denied you that privilege?

Mr. KENNEDY. The representative of the Vicksburg Laboratory, flexible pavement laboratory, on the job at the site at the test section during the conduct of the test.

Mr. HARDY. Tell the committee just what transpired. Did you ask him for a straightedge?

Mr. KENNEDY. I did.

Mr. HARDY. Did he have a straightedge?

Mr. KENNEDY. No.

Mr. HARDY. Did you have a straightedge that you offered to use?

Mr. KENNEDY. No. We don't carry a 12-foot straightedge with us.

Mr. HARDY. Well, it might be a little difficult to put in your pocket. But I am having a little trouble understanding how you were denied the privilege of using a straightedge, and I believe that is the way you expressed it.

Mr. KENNEDY. That is exactly it. I perhaps should amplify on that point.

The measurements of deflection and subsidence——

Mr. HARDY. My point is this: If he didn't have a straightedge, how were you denied?

Mr. KENNEDY. Well, there was a definite purpose in the test operation not to have visitors use a straightedge, I was so told.

Mr. HARDY. Who told you that?

Mr. KENNEDY. The representative of the Vicksburg flexible pavement laboratory.

Mr. HARDY. Told you that no one would be permitted to use a straightedge?

Mr. KENNEDY. Yes, sir; that is correct.

Mr. HARDY. Did you offer to go get one and bring it out there and try it?

Mr. KENNEDY. No, I did not; having been——

Mr. HARDY. There was no straightedge present?

Mr. KENNEDY. Correct.

Mr. HARDY. But you were denied the right to use it?

Mr. KENNEDY. Yes, sir.

Mr. HARDY. I would like to understand that a little bit better, and if it is a fact that a straightedge presented a reasonable test in that kind of a situation, if that is a fact, and it is a further fact that the right to even use a straightedge was denied, I would like to know why, and by whom.

Mr. CUNNINGHAM. Does the gentleman yield there?

Mr. HARDY. Yes.

Mr. CUNNINGHAM. I would like to know whether or not the witness was in position to get a straightedge and would have gotten one if he had been permitted to use that?

Mr. KENNEDY. No; I would do that on an Air Force base. I certainly would not——

Mr. CUNNINGHAM. Of course, if you were given permission to, you would have, wouldn't you?

Mr. KENNEDY. Oh, sure.

Mr. CUNNINGHAM. That is my question. If you had been told that you could use one, you would have had one?

Mr. KENNEDY. Yes.

Mr. HARDY. I have a litle trouble understanding that whole procedure, if it is true that a straightedge is a normal means of determining the effect of the traffic on that runway and you made the suggestion that you be permitted to use one and you were denied it, I would like to know who denied it, specifically, the individual.

I want to know who did it so we can find out why.

Mr. KENNEDY. I will be very happy to submit that for the record.

Mr. HARDY. Can't you tell us?

Mr. KENNEDY. I don't have the man's name at my fingertips.

Mr. CUNNINGHAM. But he was a representative of this company?

Mr. KENNEDY. Very definitely.

Mr. CUNNINGHAM. I have forgotten the name of it.

Mr. KENNEDY. Of the Vicksburg Flexible Pavement Laboratory of the Corps of Engineers.

Mr. HARDY. I think we ought to try to find out, if we can, right now. Maybe he is in the room. Maybe he can testify right now, because I think that is important.

Don't you have any way to determine who it was?

Mr. KENNEDY. Oh, yes. Our records will indicate that.

Mr. HÉBERT. Will you give the committee the name of the man?

Mr. KENNEDY. I will.

Is somebody in the back of the room trying to hold his name up?

Mr. FOSTER. I can explain that if you would like to have that.

Mr. HÉBERT. Stand up, please. What is your name?

Mr. FOSTER. Foster. I am from the Vicksburg Experiment Station and was in charge of the test at Columbus. While I was not the man that denied him the straightedge, I instructed the man who denied him to use the straightedge. We were operating the test under the premise that any of industry could come and observe anything they wanted to, but no test data would be made available to them until it was presented to this commitee.

Mr. HÉBERT. Well, the same would have been denied the asphalt people.

Mr. FOSTER. Yes, and the use of the straight edge would have permitted them to obtain test data. Now the straight edge was at Columbus. It was not in the shack but it was there and could have been obtained at a minute's notice. But we were operating under the instructions that none of industry would be permitted to have any of the test data until it was presened to this committee.

Mr. CUNNINGHAM. That clears it up.

Mr. HÉBERT. The same denial would have been made the Asphalt Institute.

Mr. KENNEDY. Obviously.

Mr. HÉBERT. I am glad to clear these statements up. As I said before, Mr. Kennedy, it is what you don't say that we are interested in.

Mr. HARDY. I wonder if we could clear up one thing.

Mr. Foster.

Mr. HÉBERT. Mr. Foster.

Mr. HARDY. Mr. Foster, do you have any data showing what a straight edge did show?

Mr. FOSTER. Yes. The report which was submitted to you by the Corps of Engineers——

Mr. HARDY. Does it contain—and I haven't seen it, Mr. Chairman. I was unable to attend the hearing the other day, but the report which was submitted does show data indicating the deviations which would have shown by the application of a straight edge.

Mr. KENNEDY. Yes, sir.

Mr. HARDY. Thank you.

Mr. HÉBERT. Mr. Courtney.

Mr. HARDY. Now, just one minute before we go on.

Mr. Kennedy, I would like to inquire whether you dispute any of the data which that report showed with respect to the deviations disclosed by the use of a straight edge?

Mr. RAY. Whether we dispute the data?

Mr. HARDY. That is right. Now, it has been testified that the report of the Chief of Engineers did contain the data which Mr. Kennedy says he was not permitted to gather for himself.

Mr. KENNEDY. Mr. Hardy, we agree with all of the data published in the report because it is the basis of that data that shows the deviation that is placed on these charts and shows that the end result did not meet the tolerance requirements.

It is on the basis of that data that proves that the pavement test failed.

Mr. HARDY. Well, I was concerned at the moment about this straight-edge business.

I think I can understand that it would have been rather a ludicrous sort of situation to have had everybody out there that was interested in it, in the test running all over the runway with a straight edge, but if the data with respect to the deviations which a straight edge would disclose were contained in the report, I find no particular substance in your point that a straight edge was not available to you.

The point that I was trying to understand is whether or not you dispute any of the information which the report contains.

Mr. KENNEDY. The data became available on release at the beginning of these hearings. We had access to no data, as Mr. Foster has properly stated, during the conduct of the test. Therefore, in visiting the site it was impossible to know what was going on as far as accurate measurements is concerned.

In such a situation the straight edge is an excellent everyday device for observing the relative differentials.

Mr. HARDY. I can understand that, but you are not disputing the accuracy of the engineers' data?

Mr. KENNEDY. Not in any way whatsoever.

Mr. HARDY. That is fine. Thanks.

Mr. HÉBERT. Mr. Courtney.

Mr. COURTNEY. If that be true then, Mr. Kennedy, what inference did you expect the committee to draw from your statement that you were denied the use of a straight edge during the course of this test?

Mr. KENNEDY. Well, as the test progressed there occurred a good deal of rutting and subsidence and deviation from the original surface.

Mr. COURTNEY. No. Specifically the question is this: Since you have admitted to Mr. Hardy that you did receive the results published by the engineers on a test conducted with a straight edge and you complained in your opening statement that you were not allowed the privilege of making a straight edge yourself and since you say you were satisfied with the data which you received, what inference did you expect the committee to draw from your statement that you were, during the course of this test, denied the use of a straight edge? What did you want the committee to understand?

Mr. KENNEDY. Well, I would think it would be this, that having testified twice before the committee in its earlier hearings, it would be understood that in visiting the site I would not be classified as the sidewalk superintendents who are referred to in the testimony that you heard the other day, but that I would be there for a sound purpose. And in visiting the site of an engineering operation, it is customary for the visitor to try to learn as much about the project as is possible.

Mr. COURTNEY. Well, is your complaint about a social barrier or a denial of information?

Mr. KENNEDY. A denial of information.

Mr. COURTNEY. Yet you had the information in the report which was given to the entire industry, yourself included?

Mr. KENNEDY. Correct.

Mr. COURTNEY. And it is from that report, or is it from that report that you have made or given your testimony here today?

Mr. KENNEDY. It is.

Mr. HARDY. Mr. Chairman, if I might be permitted, since I raised this point——

Mr. HÉBERT. Mr. Hardy.

Mr. HARDY. I am glad this has been cleared up because frankly I got an impression from your statement about denial that I didn't like to have. There was a clear implication left with me that the engineers or the testing laboratory or whoever was responsible for it were deliberately preventing interested people from checking on what they were doing, and it left me under the impression that you were disposed to disbelieve some of the information which you got and caused you to believe that the tests were not properly conducted or that the report was not properly made.

I am glad to have that cleared up because I don't think we ought to have any such inference as that left, unless you have a basis to contend that the information which the Corps of Engineers put in its report is not entirely valid.

Mr. HÉBERT. Mr. Courtney, any further questions?

Mr. COURTNEY. Yes, I have just one question, Mr. Kennedy. Maybe two, perhaps.

Mr. Kennedy, you have spoken of a test for a further and heavier load which is being conducted on concrete or cement, I guess you would call it, cement pavement, by the testing laboratory at Cincinnati, which is within the knowledge of the committee, as I explained to you.

Now, I will ask you whether or not there have been any tests conducted of cement pavement in use on the present and forecast loads to test the design which is now in use? In other words, has your present design criteria which you say is the answer to the Air Force problem—been tested independently in the same fashion that the asphalt paving was tested, and, if so, when?

Mr. RAY. Since 1946, sir, the Army engineers, through their Rigid Pavement Laboratory, or their Concrete Pavement Laboratory, at Cincinnati, have been conducting continuous tests, at Lockburne Air Force Base, and at a site near their laboratory at Sharonville, Ohio. These were reported on by Mr. Sale of the Chief's office at the last hearing. They started with B–29 landing gears.

Mr. COURTNEY. Right.

Mr. RAY. They worked up to B–36 landing gears. They worked up to heavier landing gears, B–47's. As each plane has come along they have made tests of pavements to correlate them with their design theory. I believe he reported they were convinced that their design theories were adequate for the aircraft in question at that time, and the future ones they are now working on.

Mr. COURTNEY. Well, as you probably know, I come from the Middle West. Perhaps you would like to express your judgment to the committee, with accompanying photographs, on the condition of the Duluth Air Force Base or the condition of the Grand Forks Air Force Base. I won't ask you to do it now, but I will ask you have you seen either of these two bases?

Mr. RAY. I personally haven't seen either one. I have seen reports on both bases.

Mr. COURTNEY. I will ask you whether or not any plane has ever taken off the Duluth Air Force Base?

Mr. RAY. Well, the Duluth—they have taken off at Duluth Air Force Base, but it has been in operation for several years, as such.

Mr. COURTNEY. I am talking about the runway that is in there right now.

Mr. RAY. There is some new pavement under construction there, and I do not know whether that is in operation today or not.

Mr. COURTNEY. Well, would you give the committee within a few days, because the record is about to be closed, the benefit of your judgment on the construction and utility of this new runway?

Mr. RAY. Yes, sir; I would be pleased to.

Mr. COURTNEY. With accompanying photographs.

Mr. RAY. We would be pleased to.

Mr. COURTNEY. And will you also tell us the amount of the repair under construction right now.

Mr. RAY. If we can obtain that now. Those figures are in the hands of the Corps of Engineers. We will have to——

Mr. COURTNEY. Well, you have a contractor up there.

Mr. RAY. Well, that contractor doesn't work for us, sir. We have no connection with him.

Mr. COURTNEY. If you can't get them, will you advise the committee and we will supply them?

Mr. RAY. Yes, sir.

Mr. KENNEDY. Be glad to.

Mr. COURTNEY. Now, do the same thing with respect to the Grand Forks Air Force Base.

Mr. RAY. Yes, sir.

(The information referred to is as follows:)

PORTLAND CEMENT ASSOCIATION,
Chicago, Ill., December 15, 1958.

HON. F. EDWARD HÉBERT,
Committee on Armed Services, Chairman, Subcommittee for Special Investigations, Old House Office Building, Washington, D. C.

DEAR MR. HÉBERT: As requested by the committee during the hearings on December 5, the questions posed by Mr. Courtney have been investigated. They relate to pavement at the Grand Forks and Duluth Air Force Bases. Attached are our reports based on these matters.

During the week of December 8 our engineers inspected the pavements at both locations. The information they obtained agrees essentially with data made available to us by the United States Army Corps of Engineers. Weather conditions at both bases precluded the taking of photographs for this report.

I trust that the information in the attached reports meets the request of the committee.

Yours very truly,

G. DONALD KENNEDY.

REPORT ON CONCRETE PAVEMENT CONSTRUCTED AT GRAND FORKS AIR FORCE BASE IN 1956 AND 1957

The concrete airfield pavement at Grand Forks Air Force Base, N. Dak., was built during the construction seasons of 1956 and 1957. As construction agency for the Air Force, the United States Army Corps of Engineers was awarded 2 contracts calling for slightly more than 1 million square yards of airfield pavement. This pavement was provided to accommodate the operations of both Air Defense Command and Strategic Air Command. It included a heavy-duty run-

way 300 feet wide and 12,350 feet long, operational aprons for both commands, taxiways, alert facilities, and a warmup pad at the end of the runway. Due to the different types of aircraft assigned the 2 using commands, the pavement ranged in thickness from 11 to 24 inches.

A minor amount of cracking has occurred in the concrete pavement, principally in the portion constructed in 1957. Engineers of the Corps of Engineers Rigid Pavement Laboratory have surveyed the pavement at Grand Forks and arrived at the conclusion that the pavement cracks resulted from movement caused by frost action in the subgrade.

There are 138 panels so affected out of a total of 15,207 panels, amounting to less than 1 percent. The cracks have been grooved and sealed. This work, together with additional drainage, cost $30,000. The pavement is entirely adequate for all operational uses.

REPORT ON CONCRETE PAVEMENT CONSTRUCTED AT DULUTH AIR FORCE BASE IN 1958

A concrete runway 150 feet wide and 9,000 feet long was built at Duluth Air Force Base, Minn., during the construction season of 1958. The United States Army Corps of Engineers let two contracts for this work which was completed October 8, 1958, and accepted by the Air Force on October 28, 1958.

One-thousand-foot sections at each end of the runway were 11 inches thick and the remainder of the runway pavement was 10 inches thick.

Some uncontrolled transverse cracking occurred in the runway pavement during construction. This was apparently due to the curing method employed which did not permit the contractor to saw contraction joints early enough. The curing method was changed on the final 3,300 feet of runway construction and, at the same time, a new type of joint construction was initiated. No further difficulty was encountered.

The corrective measures taken at Duluth consisted of removal and replacement of 1,320 square yards, or less than 1 percent of the runway pavement. In addition to this replacement, 265 linear feet of minor cracks were grooved and sealed. The cost of this work was $40,000.

The runway is now in full operational use by the jet fighter planes assigned to the base.

Mr. COURTNEY. And those are two that I happen to know about. Because we want the record to reflect the full judgment of the industry on the utility of various classes of pavements, since we must reply—and I speak for the committee in that respect—upon the engineering judgment of the Corps of Engineers.

Mr. RAY. Yes, sir.

Mr. COURTNEY. As expressed to the committee.

Mr. RAY. We will have to get information from them as to thicknesses and construction data.

Mr. COURTNEY. Those are the only questions I have.

Mr. HÉBERT. Thank you, gentlemen, very much.

Mr. KENNEDY. Thank you, Mr. Chairman, and members of the committee.

Mr. HÉBERT. Always glad to see you, Mr. Kennedy.

Mr. KENNEDY. Thank you, sir.

Thank you, Mr. Courtney.

Mr. COURTNEY. Now, the next is the Asphalt Institute, Mr. Chairman.

Mr. Buchanan, are you going to speak?

Mr. BUCHANAN. Mr. Wellborn is our spokesman, Mr. Courtney.

Mr. COURTNEY. Mr. Chairman, the technical report of the engineers, No. 3–4901, which has been under discussion with Mr. Kennedy, is a part of the printed record in this case in this matter, and in it is contained the data with reference to the straight-edge testing of the Columbus test.

Mr. Chairman, the Chief Engineer of the Asphalt Institute, Mr. Arvin S. Wellborn, is here present and has a prepared statement. He is accompanied by Dr. Buchanan, who is the president of the Institute.

Mr. HÉBERT. May I ask one thing before you testify? As representatives of the Asphalt Institute, you are not contractors?

Mr. BUCHANAN. We are not contractors. We represent an engineering organization, Mr. Chairman.

Mr. HÉBERT. But you are not contractors?

Mr. BUCHANAN. We are not.

Mr. COURTNEY. Nothing to sell.

Mr. BUCHANAN. Not as a product.

Mr. HÉBERT. In other words, your position is the same as the cement industry? They sell only the product, but they are not contractors?

Mr. BUCHANAN. We are not construction contractors, Mr. Chairman. We represent the majority of producers of petroleum asphalt in this country from the standpoint of engineering use and good application.

Mr. HÉBERT. That is again what I want the record to show.

Mr. BUCHANAN. Yes, sir.

Mr. HÉBERT. As I suggested when Mr. Kennedy was testifying, they had certain implications left from things he didn't say, and it was rather confusing. The implication was that the people who appeared to testify in favor of asphalt were contractors, and they were pro bono publico citizens on the other side. But I want both of you to be pro bono publico.

Mr. BUCHANAN. Mr. Chairman, would it be appropriate at this time for this record to make mention of the fact that in my previous testimony, I believe last August, we entered in the record a complete statement about the Asphalt Institute, and what was said then still applies?

Mr. HÉBERT. I know it. I recall it very well.

Mr. BUCHANAN. Yes, sir.

Mr. HÉBERT. And that created a question in my mind as to what Mr. Kennedy was trying to leave with the committee.

Proceed.

STATEMENT OF ARVIN S. WELLBORN, CHIEF ENGINEER OF THE ASPHALT INSTITUTE

Mr. WELLBORN. Mr. Chairman and members of the subcommittee, I appreciate the opportunity to appear today and present the views of the Asphalt Institute. It is always a pleasure to come before this group. In 4 years of exploring the subject of military airfield paving policy I have been impressed with the committee's unfailing courtesy and earnest concern for the facts.

Mr. Hébert, in his opening remarks on Tuesday, reviewed in broad outline the history of these hearings, going back to 1954. I will not detain you by plowing the same furrow, but, with your permission, I would like to refresh your memories on a couple of salient points.

First, you will recall that this series of hearings developed out of a change in paving policy adopted by the Air Force 5 years ago. At that time the Air Force expressed a preference for portland cement concrete paving and sought to nullify asphalt paving's competitive

advantage by establishing a preferential cost differential of 5 percent in favor of concrete.

This 5-percent differential was disallowed by your committee, which, however, directed that certain so-called critical areas would be constructed of concrete. Elsewhere on the paved areas the two pavement types were to continue in direct competition.

This was the first of a series of concessions which in the intervening years has been the criteria for critical areas extended to encompass taxiways and the ends of the runways. Now it seems that the Air Force is proposing to define the center 75-foot strip of the runway as a critical area by the simple device of calling it a taxiway.

It is becoming increasingly evident that total elimination from the airfield picture of asphalt paving, with all of its economic and engineering advantages, is occurring.

I would like to remind the committee that at no time has the Asphalt Institute wavered in its basic contention that asphalt paving not only can accommodate our heaviest aircraft safely and efficiently on runways and taxiways, but is doing it right now.

And this brings us to the purpose of the current hearings. Approximately a year ago a spokesman for the Corps of Engineers, United States Army assured this committee that asphalt-paved runways can be built which will serve the normal operational requirements of the B–52 aircraft. At the insistence of this committee, and with the Air Force concurring, this project was undertaken at Columbus Air Force Base, Miss.

On Tuesday, we heard from the Corps of Engineers on the results of this pavement test. We heard General Wilson and General Brown, of the corps, report that the accelerated test at Columbus had, indeed, demonstrated the validity of their design for flexible runway interior pavements. We heard Mr. Ferry, of the Air Force, concur in the report.

First, I would like to invite your attention to the statement of the Corps of Engineers:

> To the extent that the statement limits itself to conclusions predicated on the purpose of the test, the Asphalt Institute is in full agreement with the Corps of Engineers.

We believe the test at Columbus completely vindicates our position from the outset.

Mr. Chairman, we are prepared to accept that portion of the corps' report dealing specifically with the announced purpose of the test, with two qualifications which, with your permission, I will now try to develop for you.

Two areas of pavement deformation occurred under the test traffic. One was a 5/8-inch depression running transversely across the pavement in the immediate vicinity of the buried-slab transition between the asphalt-paved test section and the adjoining concrete. The other was an average 1¼-inch subsidence of the pavement in the wheel lane resulting in a differential settlement between the trafficked area and the areas on either side which carried no traffic.

Taking them in order:

First, let us consider the transition joint roughness in its proper perspective. This depression of about a half an inch has developed over a hypothetical period of 20 years. Assuming we have identical

conditions at both ends of the asphalt-paved runway, we have General Wilsons' testimony that the total cost of correcting this deficiency at the end of 20 years would be only $1,000 and could be done in a single day.

But of greater significance, I believe, is the general's statement that the joint design was not satisfactory and that an improved transition should be possible. In this respect, I will go one step further and assure this committee that such an improvement not only should be possible, but is possible. This minor pavement deflection at the transition area can be designed right out of further consideration.

With respect to the pavement subsidence which developed in the traffic paths, I would like to offer these observations for the committee's consideration:

(1) In his testimony on Tuesday, General Wilson stated that this would not be expected to occur under normal, prototype B–52 traffic.

I would like to repeat that, Mr. Chairman. In his testimony on Tuesday, General Wilson stated that this would not be expected to occur under normal, prototype B–52 traffic. It was peculiar to the conditions of the test which limited traffic to a 14-foot traffic lane, and consequently it may be discounted as irrelevant. Normal prototype traffic would be distributed over a 75-foot width of pavement.

(2) We heard testimony that it would require normal operational taxiway use of the pavement over a period of 6 months to produce this "slight grooving," as General Wilson described it. There is no reason to expect a runway to be used as a taxiway for such an extended period. General Kingsbury, the commander of a B–52 wing at Walker Air Force Base, testified that six planes are exercised each week on an operational alert which would require use of the runway for taxiing purposes, and Mr. Ferry suggested that the runways are frequently used as taxiways when the regular taxiways are closed down for repairs. This strikes us as being pure hypothesis since the taxiways are now concrete and the Air Force assures us that they rarely require repair.

(3) Over the calculated period of 20 years, represented by the test, the pavement deformation amounted to an average of only 1¼ inches. In normal use any pavement consolidation would be corrected, quickly and economically, with a simple repair operation as soon as it became evident. In fact, normal maintenance procedures over the span of years would correct the condition automatically before it became a problem.

Finally, I will invite your attention to the summary of findings on the Columbus test. The problem of channelized consolidation of the pavement need never arise again. The one conspicuous lesson learned from the Columbus project was that additional compaction in the base structure of the pavement will eliminate 85 percent of the later consolidation under heavy wheeled traffic.

And, speaking of this additional compactive effect of the test traffic, I think it is worth emphasizing at this point an observation made in General Wilson's statement, and confirmed by General Brown. I will quote from General Brown's statement. This is a direct quote:

The pavement deflections did not increase with coverages and even showed a slight decrease at 5,000 coverages as compared to the value at 3,500 coverages. This is evidence that the strength of the material under the asphaltic concrete increased with traffic.

Mr. Chairman, this is a very significant point. The 200-foot test section of asphaltic concrete pavement at Columbus Air Force Base has now received a simple and inexpensive sand-asphalt seal and at this moment it is a stronger, smoother, more durable pavement than it was on September 4 when the testing began. And additional seals, applied over a span of years, can extend the service life of that pavement almost indefinitely.

I do not believe the same can be said for those adjoining concrete slabs which developed cracking although not directly subjected to the test traffic.

I will turn now to the testimony offered by the Navy.

Mr. Chairman, the Navy has introduced an entirely new factor into these discussions. Until Tuesday we had no knowledge that the Navy was grappling with this special problem of pavement "toughness," to borrow Admiral Pelletier's word. We have no reason to question the Navy's assertion that excessively high tire pressures—ranging up to 400 pounds per square inch—can create a special problem with respect to tearing or displacing most standard paving mixtures. Neither have we any reason to believe that an asphaltic pavement cannot be designed to resist this type of abrasion. We would welcome the opportunity to work with the Navy in this matter.

In his testimony on Tuesday, Admiral Pelletier said the Navy's position in this regard is open if it can be demonstrated that flexible-type pavements can perform satisfactorily for traffic with high-pressure tires.

I would like to propose, if it is agreeable with this committee, that the Navy be permitted to apply a test representative of its own aircraft, to the section recently employed for testing heavy wheel loads at Columbus. I have reason to believe that such a test would disclose that this type pavement can accommodate the very high tire pressures peculiar to carrier-type aircraft.

In this repect, incidentally, I would like to correct what I regard as an erroneous evaluation by the Navy of the construction work at Columbus. The test section at Columbus was not built under ideal conditions. In fact, it was a requirement of the test that the pavement should be built as a representative construction project using locally available materials. This the Corps of Engineers made every effort to do, and we are completely satisfied that they accomplished their objective.

In fact, the Columbus pavement was built under conditions that were far from ideal. There were problems involving inferior local aggregates and the project was harassed by almost incessant rains. These rains, the heaviest and most unrelenting in years in this area, saturated the base materials and seriously jeopardized the entire project.

Finally, if it is not practicable to run such a test at Columbus by the Navy, or if the pavement now in existence at Columbus failed to perform up to our expectations, I am still entirely confident that the Navy's problem offers no insurmountable challenge. We have had considerable experience with paving design for industrial flooring where the surface is subjected to extremely heavy loadings borne on solid rubber tire and narrow steel wheels. It is entirely possible that the solution to the Navy's problem lies here, in the area of extremely stable and tough mixtures.

I do not propose to burden the record with a lengthy discussion, Mr. Chairman, and this constitutes the essence of our remarks at this time. However, I will conclude with an observation which relates directly to the testimony offered by the Government agencies on Tuesday.

We heard the Air Force propose a new compromise adjustment in paving criteria for military airfields—to construct a centerline strip of rigid pavement down the runway to serve incidental taxiway requirements. We also heard the Corps of Engineers endorse this idea.

We do not agree that this extreme measure is necessary, or even desirable. However, even in contemplating it, it raises some interesting questions.

If this is an acceptable design for taxiway traffic—and this seems to be the burden of the new Air Force position—then I believe it's time to back up and review the whole airfield paving picture. Why not apply this design to the taxiways? Why not build a center traffic strip of rigid pavement flanked by two subordinate strips of asphalt pavement? The Air Force, by its own testimony, has stated that this is entirely appropriate and acceptable design for taxiway requirements.

We understand that the taxiways at Columbus are built this way. Why not build all taxiways in a similar manner?

In the testimony offered Tuesday it was explained that these very heavy military aircraft carefully follow the center strips on the pavement as they taxi into position and takeoff. This being the case, why carry the rigid pavement design to the full width of the taxiway simply to support the occasional light load of the outrigger gear?

Mr. Chairman, we must not lose sight of the economic aspect in these hearings. It is in the public interest to preserve a competitive paving policy. Experience has shown us that, when one type of pavement is granted an exclusive franchise, inflated costs are the inevitable consequence.

We believe the pavement test at Columbus has proved that asphalt-paved runways can serve the requirements of modern heavy military aircraft, now and in the foreseeable future. In the interest of preserving the integrity of the Nation's construction dollar, we feel that the provision requiring competitive, alternate bidding for interior runway construction should be retained—and that we should consider seriously revising our present design criteria for taxiways.

Mr. Chairman, this completes my prepared statement. However, before leaving the stand, I would like to respectfully request that the Asphalt Institute be permitted additional time to study the Department of Navy report on rigid and flexible type pavements for naval and Marine Corps air stations, dated May 1958. We received a copy of this report only last weekend and circumstances have prevented our complete analysis.

Although the Navy report was somewhat discredited by Admiral Peltier as expressing the Navy's findings, it will become a part of the record, and contain statements that may not be factual.

Therefore the Asphalt Institute may wish to submit a statement at a later date regarding this report for the record.

Thank you, gentlemen.

Mr. HÉBERT. How long would it take you to have such a report?
Mr. WELLBORN. Next week.
Mr. HÉBERT. Next week?
Mr. WELLBORN. Yes, sir.
Mr. HÉBERT. You have permission.
Mr. COURTNEY. Mr. Chairman, it is not planned to close the record and submit it to the printer until December 20.
Mr. HÉBERT. Then you have until December 20.
(The material referred to appears in appendix A.)
Mr. WELLBORN. Yes, sir.
Mr. HÉBERT. Mr. Cunningham?
Mr. CUNNINGHAM. No questions.
Mr. HÉBERT. Mr. Hardy?
Mr. HARDY. I was interested in the statement that appears on page 3, that the subsidence or the depression which occurred at the Columbus test at the end of the concrete slab represented what would have occurred in the period of 20 years.
And only $1,000 would have corrected that deficiency.
Did I understand that correctly, that the depression that resulted there was after a simiuated operation of 20 years, and it would take only $1,000 to correct it?
Mr. WELLBORN. That is General Wilson's direct testimony. In fact, he said that it would not require $200 for this particular depression.
Mr. HARDY. Well, normally that wouldn't have been permitted, then, to get that deep in the course of normal operations before it was corrected; is that right?
Mr. WELLBORN. In my opinion, no, sir; it would not have been permitted.
Mr. HARDY. Now, on page 5 of your statement you discuss a test, concerning the subbase design, and you say:

> It was the requirement of the test that the pavement should be built as a representative construction project using locally available materials.

Well, now, you probably heard the discussion of Mr. Kennedy a while ago about the use of the materials that were employed in the Columbus test. Is it or isn't it a fact that the materials available at that particular site were of a very fine, high type, and very readily adaptable for that particular purpose, for compaction?
Mr. WELLBORN. For compaction, probably some of the material was. However, for a high-class base-course material and for high-class asphaltic concrete, it was not. I would rather, though, have the Corps of Engineers answer such a question as that because they evaluated the materials.
Mr. HARDY. Well, didn't you evaluate the material, too, as an engineer?
Mr. WELLBORN. Yes, sir.
Mr. HARDY. And it is your conclusion that they were not the most desirable type?
Mr. WELLBORN. They were desirable for the purpose. However, there are much better materials than were used.
Mr. BUCHANAN. Elsewhere.
Mr. HARDY. Well, now, if you are going to restrict construction of runways to the use of locally available aggregates or materials for subbase, would it be expected that on the average site or in the average

locality there would be available better or less suitable materials than were available at Columbus?

Mr. WELLBORN. It is my understanding that it is peculiar to the area of Columbus. It is in the area of the Gulf Coastal Plain, and by the time aggregates have reached that far south they have been washed around pretty well by the water.

Mr. HARDY. Not so sharp?

Mr. WELLBORN. Not so sharp and they have a tendency to be softened, then glacial aggregates farther north.

Mr. HARDY. I was going to say, as far as sharpness is concerned, that doesn't make too much difference in the matter of compaction, does it?

Mr. WELLBORN. No, it does not.

Mr. HARDY. So that would make a pretty solid base. Now, maybe the hardness would be more important; is that what you mean?

Mr. WELLBORN. That enters into the design of the mixture; yes, sir.

Mr. HARDY. There are a lot of areas where you would have less suitable materials than were available at Columbus; isn't that correct?

Mr. WELLBORN. Yes, sir.

Mr. BUCHANAN. That is right.

Mr. HARDY. So you might have a greater difficulty in securing a proper fill material in other places than you had at Columbus?

Mr. WELLBORN. Oh, surely, yes. Conversely, there would be places where there would be better materials.

Mr. BUCHANAN. That is right.

Mr. HARDY. Well, that is what I was trying to understand, whether that was reasonably representative of the average or whether there would be other locations in which the cost of securing suitable aggregates might be too expensive and make concrete actually less costly to build.

Mr. WELLBORN. That is possible, yes. I will admit that. That I think emphasizes the importance of competitive bids, to be sure that one is cheaper than the other.

Mr. HARDY. In which case the specifications with respect to the material to be used in your subgrade would have to be pretty carefully spelled out?

Mr. WELLBORN. It is, sir. They are spelled out in the specifications.

Mr. HARDY. Well, what I am talking about is, you couldn't use the yardstick of getting only locally available aggregates?

Mr. WELLBORN. Well, I think the Corps' procedure is to use locally available aggregates if they are available. Naturally, economics comes into the picture.

Mr. HARDY. And of a satisfactory quality.

Mr. BUCHANAN. If they are acceptable, yes.

Mr. WELLBORN. That is right.

Mr. HÉBERT. Mr. Courtney?

Mr. COURTNEY. Just one question.

When you speak of competitive bidding you, of course, refer to the fact that the competitive specifications must be the subject of the bid?

Mr. BUCHANAN. That is right.

Mr. WELLBORN. That the designs be predicated on comparable conditions.

Mr. BUCHANAN. And comparable performance; performing the same service.

Mr. COURTNEY. The same service.

Mr. Buchanan, did you have any comment?

Mr. BUCHANAN. Mr. Courtney and Mr. Chairman, I should like to make a comment about one of the charts used by my worthy competitor, if I might.

Mr. COURTNEY. You are not selling anything now, though.

Mr. BUCHANAN. But I want to be sure that the wrong impression is not left with this group.

Now, if Mr. Kennedy is here, I would like to request—I think it is his chart No. 2.

If not, this is the one I am talking about. And I can refer to it from this document.

Mr. HÉBERT. That document is a part of the record.

Mr. BUCHANAN. My point is, if my arithmetic is correct, that on the horizontal scale I believe—that is as compared with the vertical scale which presumes to show the deformation I think it is called, I think the magnification is in the order of 150 to 1. I wouldn't like to have the committee have the wrong impression from this magnified scale.

Now, it is true that this procedure is often used, but I wanted to bring out the difference in the two scales, horizontal as compared with vertical, so that this thing would be interpreted in proper perspective.

Horizontally, this distance represents 200 feet, and this represents 2 inches—this represents 3 inches, since it is plus—it goes up to plus 1 to minus 1.

Mr. COURTNEY. Let the record show, Mr. Chairman, that that is the drawing which follows page 14 of the printed presentation.

Mr. BUCHANAN. That is the one I am talking about.

Mr. COURTNEY. Yes, sir.

Mr. HARDY. That observation would apply to all of the comparable photographs that were in this submission, would it not?

Mr. BUCHANAN. This chart I think does not have the same magnification, but there is magnification there. In this instance the horizontal scale represents 24 feet, and again the vertical distance represents 3 inches, marked off there. The magnification would not be the same, however.

Mr. COURTNEY. That is the chart which follows page 15.

Mr. HARDY. Of course, it makes the depression show up pretty sharply when you relate it to such a short distance.

Mr. BUCHANAN. That is my point, sir.

Mr. COURTNEY. You are speaking of distortion, Doctor?

Mr. HARDY. If there wasn't any distortion you wouldn't be able to show it so you could understand it?

Mr. BUCHANAN. That is right.

Mr. HÉBERT. As engineers, do you find any difficulty in submitting two designs, cement as contrasted to asphalt, for an invitation to bid? Is there any great amount of weight attached to that?

Mr. BUCHANAN. There is some extra design work; yes, sir. It is not insurmountable. In most instances the savings far exceed and offset the extra design costs. And I believe, subject to verification by the Corps of Engineers people, I believe the Corps of Engineers has on many occasions used the alternate design competitive bid procedure.

So it is not an unprecedented or unusual thing. Many State highway departments do the same thing. Many architects do.

Mr. HÉBERT. And they do it without great difficulty?

Mr. BUCHANAN. Yes, sir.

Mr. HÉBERT. It is a common practice, then, to submit alternates in this industry?

Mr. BUCHANAN. Yes, sir.

Mr. HÉBERT. For construction?

Mr. BUCHANAN. Yes, sir. And it certainly is not an uncommon practice. There is a little difference in emphassis there. But it certainly is not an uncommon practice. On many of the great turnpikes built in recent years, competitive analysis and competitive bids were taken.

Mr. HÉBERT. The reason I ask that question: I think it was Mr. Ferry left the impression—not only the impression but I believe he also made the statement that the reason alternates were not suggested was because the prior evaluation or preestimate indicated there would be no competitive status between the two.

Now, would you accept that?

Mr. BUCHANAN. In engineering practice, Mr. Chairman, it is again not uncommon for the engineers in the design stage of the development of a project to make comparable designs and make engineering estimates and satisfy themselves in terms of the locally available materials and the costs of materials and the costs of labor and that sort of thing—satisfy themselves by engineering analysis that one design is more economical than another, and then bring out the plans and specifications for bid on that premise.

On the other hand, they sometimes, not sure of their own figures, bring out both designs and let the bidders establish the economy.

Mr. HÉBERT. I know you are not contractors, but you have contract with contractors.

Mr. BUCHANAN. And we read the contractors' bids all the time, because that is the current data as to construction cost.

Mr. HÉBERT. But do you know of any instance whereby a contractor would be indifferent toward extending a bid on an alternate, if he thought he had a chance to get the job?

Mr. BUCHANAN. Mr. Chairman, again, not being a contractor I am not sure about trying to answer that.

Mr. HÉBERT. The point that I am attempting to make is that it should be left to the contractors whether they want to bid or not?

Mr. BUCHANAN. Yes, sir.

Mr. HÉBERT. I think they should be given the opportunity.

Mr. BUCHANAN. I would agree with that; yes, sir.

Mr. HÉBERT. And not some predetermined estimate.

Mr. BUCHANAN. Right.

Mr. HÉBERT. In your experience as an engineer—not as a contractor, but your acquaintance with contractors—have you found in Government estimates that the estimates have been way out of line with the completed job on cost?

Mr. BUCHANAN. I personally haven't analyzed bids recently that accurately. My current duties do not call for that. I should like to defer to Mr. Wellborn, who keeps a closer eye on it than I, if he feels qualified to answer it.

Mr. WELLBORN. Mr. Hébert, I believe we can refer to the testimony given last Tuesday, when they said it was between 10 and 15 percent, that could mean considerable money.

For instance, if it was a $10 million project. Well, 15 percent is a million and a half dollars. Well, considerable savings could be realized if competitive bids were taken, whether it would be up or down, as far as that goes.

Mr. HÉBERT. I think you said what I was trying to point out. For instance, on a $15 million job and say that variance was between 10 and 15 percent, it would represent $1½ million.

Mr. BUCHANAN. Right.

Mr. WELLBORN. Yes, sir.

Mr. HÉBERT. Which to some people in Government probably doesn't mean anything. But we try not to enter the spending era as has been predicted and are trying to retract a little bit.

Mr. HARDY. Mr. Chairman, I would like to make one more inquiry concerning the testimony of Mr. Kennedy.

He had a picture that impressed me right much, of the Columbus test taken just after a rain.

Now, I can understand that better than I can some of these engineering terms you fellows employ. You see the water standing on that runway. I would like to have you comment about that because that gives the appearance of considerable rutting.

Mr. WELLBORN. Mr. Hardy, one of the smoothest surfaces built today is a tennis court, and I would like to request you or ask you that the next time you look at a tennis court after a rain, notice the surface. The great tolerances of a tennis court are almost as smooth as a pool table.

Now, if you will look at this, you will notice that the water depth is practically nil because it doesn't even distort the strip. If that is deep, if there was any depth in this puddle, well, the strip would be distorted. It is practically a complete straight line of that strip. So you know that the depth of the water is practically negligible.

Mr. HARDY. But I thought there would be a difference between the construction of a runway and of a tennis court in that I would have expected that there would be more crown in a runway so the water would run off.

Mr. WELLBORN. Mr. Hardy, again the analysis or any conclusions drawn from a picture like this or even the straight-edge data which you discussed earlier was completely discredited by General Wilson and Mr. Ferry, by the chart that he had here.

If you will remember the pyramid chart that showed the normal distribution of traffic under prototype conditions?

Then at the bottom of that chart he had what—if the traffic had been distributed normally, as would occur on an airfield, that this rutting could not have happened, and I believe that the Air Force agreed that this rutting was not consequential to the test.

Mr. BUCHANAN. This was peculiar to a concentration of traffic in a width of 14 feet; is that the point?

Mr. WELLBORN. Yes, sir.

Mr. HARDY. Is that a greater concentration than the Air Force contends they normally have in their channelized traffic operation?

Mr. WELLBORN. I believe they admitted that in their testimony. They agreed with the chart the corps had on the easel there.

Mr. HARDY. Thank you, Mr. Chairman.

Mr. HÉBERT. I suggest to Mr. Foster, you did let the other people have cameras on that field during the test. At least they had the picture?

Mr. FOSTER. That was discussed at great length and it was finally agreed to let them use a camera.

Mr. HÉBERT. I just wanted to know how they used the camera. That is all.

Mr. COURTNEY. Have you gentlemen anything further?

Mr. WELLBORN. No.

Mr. BUCHANAN. Other than the data we have filed with you.

Mr. WELLBORN. Thank you, sir.

Mr. BUCHANAN. Thank you, Mr. Chairman.

Mr. HÉBERT. Thank you for your appearance.

Mr. HARDY. Mr. Chairman, before we leave this particular aspect of these two groups of testimony——

Mr. HÉBERT. Mr. Hardy.

Mr. HARDY. In the testimony of Mr. Kennedy reference was made to two accidents at Loring Air Force Base and there was some discussion of it following Mr. Kennedy's testimony.

In view of the fact that there was some question of possible implication that the cause might have been attributed to runways, I think we should ask the Air Force to advise the committee either for the the record or if classified at least for the committee's information just exactly what their findings were with respect to the causes of those accidents.

Mr. HÉBERT. I think it is a very proper suggestion and will be done.

(The data referred to above was submitted by the Department of Air Force and is as follows:)

DEPARTMENT OF THE AIR FORCE,
Washington, December 15, 1958.

Hon. F. EDWARD HÉBERT,
Chairman, Subcommittee for Special Investigations,
Committee on Armed Services, House of Representatives.

DEAR CHAIRMAN: I refer to a letter of December 5, 1958, from Mr. John J. Courtney, special counsel to the subcommittee, in which he requested certain information concerning the causes of the two recent aircraft accidents at Loring Air Force Base, Maine. I am pleased to forward herewith the information requested.

Major aircraft accident, KC–135, 0725 eastern standard time, November 25, 1958: The KC–135 and crew, on an air refueling and standardization check, departed Loring Air Force Base at 0445 eastern standard time on November 25, 1958. The aircraft used 130,000 pounds of fuel during flight and returned to the local area to complete the standardization check. A jet penetration and ground-controlled approach was made with the aircraft touching down at approximately 2,500 feet down the runway. As power was applied, at approximately 6,000 feet down the runway for a routine go-around, witnesses saw white vapor coming from the No. 4 engine. The aircraft veered to the right, becoming airborne in an extremely nose-high and right-wing-low attitude. The aircraft struck the ground approximately 1,200 feet from the edge of the runway and was totally destroyed.

A probable cause of this accident could have been the loss of power on the No. 4 engine just before minimum control speed was reached, causing the pilot to lose directional control of the aircraft. The exact cause of the loss of direction control is still undertermined as of this date. During touch-and-go landings it is apparent that at low gross weights and low temperatures a minimum control situation can exist.

Major aircraft accident, B–47, SN 51–2199, 0900 eastern standard time, November 22, 1958: The B–47 aircraft and crew were assigned to the 321st Bomb Wing,

McCoy Air Force Base, Fla., and were on a return cross-country flight from Loring Air Force Base to McCoy Air Force Base.

The aircraft appeared to be making a normal takeoff roll and became airborne at the 8,000-foot marker at which time an excessive nose-high attitude was observed by the tower operator. The estimated angle of climb was 30 degrees and the aircraft climbed to approximately 100 feet, started a roll to the right and contacted the ground at a 45-degree dive with a 50 to 60 degree angle of bank to the right. Point of impact was approximately 500 feet east of the north end of the north-south runway at the 10,000-foot point.

Investigation to date indicates the possibility of the loss or failure of a rear-mount pin of the No. 6 engine. The loss or failure of this pin would allow the aft end of this engine to swing down severing the fuel hose and causing engine stoppage. The loss or failure of the No. 6 engine rear-mount pin appears to be the most probable cause of the engine stoppage.

Neither of these two accidents occurred on the runway. The runway at Loring Air Force Base was constructed originally 9,160 by 300 feet in 1948. It consisted of flexible pavement composed of a bituminous concrete surface, a 9-inch crushed stone base course and a 55-inch sand-gravel subbase course, and was designed for 300,000 pound loading on twin-wheel gear.

In 1952 it was extended 840 feet to the north. This section was flexible pavement composed of a 3-inch bituminous concrete surface, a 7-inch crushed stone base course and a 60-inch sand-gravel subbase, and was designed for 100,000-pound gear loading on twin wheels.

In 1955 and 1956 a 2,100-foot extension to the north was added. This was composed of a 1,000-foot rigid pavement end (portland-cement concrete), 15 inches thick on a 55-inch sand-gravel-base course, and 1,100 feet of flexible pavement having a 4-inch bituminous surface over a 6-inch crushed-stone-base course on a 60-inch sand-gravel subbase course. At this time, 1,000 feet of the south end was reconstructed with rigid pavement 15 inches thick on 55 inches of sand-gravel base. Design loading was 100,000 pounds on twin-wheel gear.

Thus, the runway is now 12,100 feet long by 300 feet wide and is composed of 10,100 feet of flexible pavement with an additional 1,000 feet of rigid pavement at each end. The flexible pavement portion was given a seal coat in the fall of 1958. The general condition of the pavement, both flexible and rigid portions is considered to be very good.

The mission of Loring Air Force Base is to support a Strategic Air Command B–52 bombardment wing and a KC–135 refueling unit.

In neither of these two accidents did the Aircraft Accident Investigation Board ascribe runway material or method of runway construction as a primary or contributing factor to the accidents.

I trust that this information will be helpful to the subcommittee. However, should any additional information be required, I shall be pleased to furnish it upon request.

Sincerely yours,

W. P. FISHER,
Major General, USAF,
Director, Legislative Liaison.

Mr. COURTNEY. Mr. Chairman, the National Bituminous Concrete Association is represented by Mr. H. K. Griffith, its executive director, and Mr. John W. Kelly, its president.

Mr. Griffith has a prepared statement and will lead off.

Mr. HÉBERT. Mr. Griffith.

STATEMENT OF H. K. GRIFFITH, EXECUTIVE DIRECTOR, NATIONAL BITUMINOUS CONCRETE ASSOCIATION

Mr. GRIFFITH. Mr. Chairman, lets' make the record clear. We are contractors. We do have something to sell if the buyer will talk to us. So far he hasn't talked to us.

The statement I have to make is with reference to the Navy's presentation on Tuesday afternoon.

We are aware of the many excellent flexible airfield pavements constructed by the Navy. In fact, many of our members have been privi-

leged to do work for them. We have received informal reports of satisfactory performance under varying conditions and usage.

However, about May of this year we heard rumors of an imminent change in Navy policy based on an official report on the condition of pavements at Navy and Marine air stations.

On June 4, 1958, we respectfully requested a copy of this report.

By Department of the Navy's letter of June 26, 1958, our request was refused. Accordingly, we had no knowledge of the difficulties stated in this report and presented in the testimony of last Tuesday. Naturally, on such short notice we have no solution to recommend, but we are sure one can be found.

In view of the Navy's position with respect to the use of flexible pavement for runways subjected to high tire pressures, we believe that further testing and developing is the proper procedure and there can be developed a solution to the problem.

We concur with the suggestions of the Asphalt Institute that a suitable test be developed and started as soon as possible on that portion of the runway at Columbus Air Force Base which has just been subjected to a test.

It is also believed that there now exists at some naval air stations flexible pavements which will successfully meet the projected requirements and which, upon the proper analysis, would indicate a solution to successful performance of flexible pavement under high-pressure tires.

Noting the openminded position of the Chief, Bureau of Yards and Docks, and with the cooperation of all segments of the industry, the two working together can find a solution to this problem.

These are copies of the documents referred to in my statement.

Mr. COURTNEY. You wish to have them made a part of the record, Mr. Griffith?

Mr. GRIFFITH. Yes, sir.

(The documents are as follows:)

JUNE 4, 1958.

CHIEF OF CIVIL ENGINEERS,
Bureau of Yards and Docks,
Department of the Navy,
Washington, D. C.

DEAR SIR: We have been advised that a report, Rigid and Flexible Type Pavements for Naval and Marine Corps Air Stations, has been prepared for the Department of the Navy. This association represents nationally contractors primarily engaged in the construction of flexible-type pavements, and since this report deals with our industry we respectfully request at least one copy if it is available.

Yours very truly,

H. K. GRIFFITH, *Executive Director.*

DEPARTMENT OF THE NAVY,
BUREAU OF YARDS AND DOCKS,
Washington, D. C., June 26, 1958.

NATIONAL BITUMINOUS CONCRETE ASSOCIATION, INC.,
Washington, D. C.
(Attention of Mr. H. K. Griffith, executive director.)

GENTLEMEN: Your letter of June 4, 1958, requested a copy of the Bureau's publication Rigid and Flexible Type Pavements for Naval and Marine Corps Air Stations.

The Bureau regrets that this publication is restricted to service use only and is not available for distribution.

By direction of the Chief of Bureau:

Very truly yours,

W. P. ECKERLE,
Assistant to the Manager,
Specifications, Supply Standards, and Estimates Branch.

Mr. HÉBERT. Any further statements?

Mr. COURTNEY. No questions of Mr. Griffith.

Mr. HÉBERT. No questions.

Mr. COURTNEY. Mr. Kelly, you have a statement.

STATEMENT OF JOHN W. KELLY, PRESIDENT, NATIONAL BITUMINOUS CONCRETE ASSOCIATION

Mr. KELLY. Mr. Chairman and members of the committee, for the National Bituminous Concrete Association and its approximately 600 bituminous paving contractors, I should like to express our appreciation to this committee for its time, patience, and very positive effort in considering the ability of asphalt pavements to economically and safely serve for the pavement on runways at military airfields.

I should also like to compliment the Corps of Engineers for its fine work, the cooperation and consideration it has shown us, and reiterate our confidence in their ability.

Some 3 years ago a high-ranking official of the Air Force publicly stated: "Concrete can take it; blacktop can't." In previous sessions of these hearings an official of the Department of Defense associated with the Air Force repeatedly said for the record that the Corps of Engineers could design, build, and test flexible pavements in their laboratory which would meet the Air Force requirements but that the contractors did not have the ability to so perform in the field. Both of these opinions have been widely circulated.

On Tuesday of this week you heard testimony by the Corps of Engineers which was very positive in nature and proved asphalt could take it and the contractor did build it. These two adverse opinions have now been discredited by the results of the Columbus test. I believe the record should now show clearly that the contractors can build asphalt runways which will economically and safely support our heaviest planes and any possible future loads.

The consulting firm of Miller-Warden Associates has been retained by our organization throughout this study to give us an objective engineering opinion. They testified before this committee in the 1957 hearings and have closely observed and followed the Columbus test. We ask that their engineering report, to be submitted later, be included in the record.

At this time, however, I would like to summarize that portion of their report dealing with the 75-foot concrete finger, in an attempt to curtail the possibility of an untimely and unwise compromise for the sake of expediency.

1. The Air Force has introduced new issues that are speculative and conjectural.

2. The premise that the flexible pavement constructed at Columbus is not suitable for occasional taxiway usage has not been proven.

3. The occasional use of the runway for taxiing purposes, aborts, or Coco missions is not comparable to the service required of a taxiway.

4. Asphalt pavements have and can be built to meet the smoothness tolerancees originally required by the Air Force despite the fact that they had to be relaxed by the Air Force in March and June of 1958 because rigid pavements could not be constructed to these desired tolerances.

For these and other reasons contained in the consultant's report, as well as the added cost and the increased operational hazard as outlined by Commander McLellon, of the Navy, in his testimony on Tuesday afternoon, we are opposed to the compromise idea of a 75-foot rigid finger.

Throughout these hearings no mention has been made until today of defects or failures of rigid pavements designed and constructed to meet the requirements of the Air Force for heaviest aircraft operation, although these defects are common knowledge in the paving industry. This omission has by implication created the impression that rigid pavement is perfect in every respect. This is far from correct. Just to take one immediate example: During the latter stages of the test at Columbus, at my own time and expense, I visited the base and observed the test. Quite naturally while I was there I took a rather careful look at the other pavement on this base, both flexible and rigid. I found extensive structural cracking in the rigid pavement on the primary taxiway which I consider to be of a serious nature. I was informed that the only traffic on this pavement had been trucks with wheel loadings a mere fraction of the airplane wheel loadings which this pavement will be required to safely support. On the concrete finger in the center of the runway not yet subjected to aircraft traffic, I observed major cracks developing in the rigid pavement. These cracks, in my opinion, under normal use could become serious structural failures unless expensive repairs are made.

On pages 184 and 185 of the transcript of Tuesday's hearing, Mr. Ferry, in reply to a question by Mr. Courtney about alternate bidding, made reference to "smart contractors." The implication in my opinion, after carefully studying the dialog, is that the only smart contractors in the business today are those very limited few who have accepted the wishes of some elements of the Air Force for rigid pavements to the exclusion of the more economical flexible pavement.

Since the implementation of the present Air Force criteria requiring the almost exclusive use of rigid pavement, there are seldom more than five bidders on a given job.

The Walker Air Force Base at Roswell, N. Mex., was discussed for the record. Let me point out that a recent contract for rigid pavement construction only at this location, amounting to over $2 million, was awarded to the one solitary bidder. I know that had there been provisions for alternate bidding there would have been at least 12 and probably 15 local contractors competing for this work. That is the way for the Government to save some money.

In Tuesday's hearing it was pointed out that no economic conclusions could be drawn or applied from the construction of the test section. However, I think this committee might be interested in some figures I have developed on the comparative cost of the two pavement types included in the test lane.

As a contractor bidding and building both types of pavement and working from headquarters in Oklahoma City, which is virtually surrounded by probably the greatest concentration of SAC bases anyplace in the United States, I have taken the exact as-built design of the Columbus test pavement, both rigid and flexible, and applied unit bid prices prevalent in my area.

I might add that I would be glad to have them at this price.

If I were to have the opportunity of bidding on a 12,000-by-300-foot runway, my bid for an all-flexible pavement of this design would be $2½ million, as shown in the top.

Using 1,000-foot concrete ends and the interior 10,000 feet of flexible pavement, the bid would increase by about $300,000. If this new idea of a compromise 75-foot-wide center strip were to be imposed, my bid would be increased by an additional half-million dollars. Since I am restricted to bid under the existing policy requiring all-rigid pavement, the best I could do would be $4,525,000. In this case, the difference in cost between a flexible-pavement runway with rigid-pavement ends and a runway entirely of rigid pavement is $1,685,000.

This amount is almost sufficient to pave a second and parallel runway 200 feet wide of flexible pavement with concrete ends. Runways of this width are in current use for B–52 operations. Space for the construction of such a parallel runway is usually provided for in the master plan of a base.

By accepting the economy of flexible pavement for interior runway construction, it is possible to provide an alternate runway which will keep a base operational during the course of any required pavement repairs, including those necessitated by possible bomb damage.

If interference with continuous operation due to pavement repairs made necessary by the possible use of the runway as a taxiway is a problem, as implied by recent testimony, here is a more realistic solution:

For less than 5 percent more than the cost of 1 runway constructed entirely of all-rigid pavement, a flexible-pavement runway with rigid-pavement ends and an alternate runway of the same type 200 feet wide can be paved. What I am saying, gentlemen, is that we are offering you 2 runways for the price of 1.

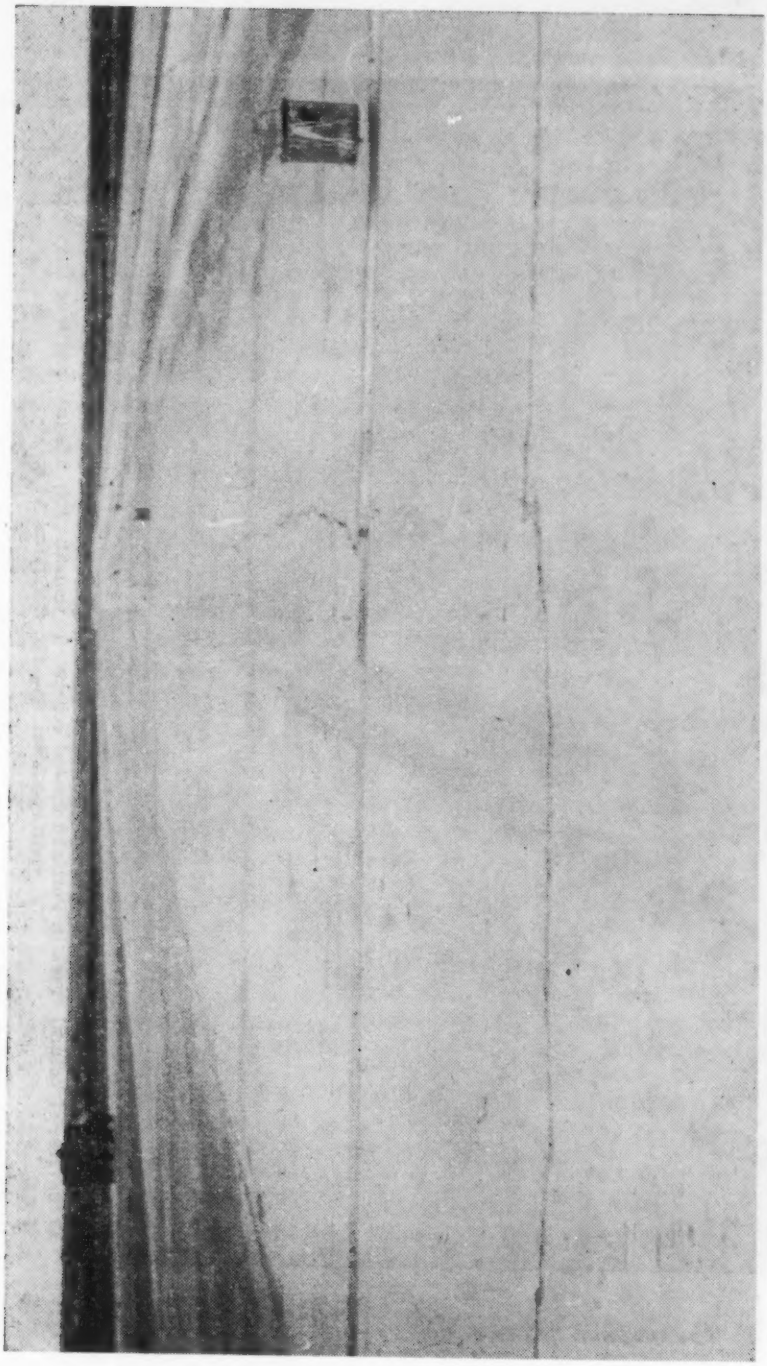
Mr. HÉBERT. By the way, did you have a camera down at Columbus?

Mr. KELLY. Yes, sir.

Mr. HÉBERT. Did you take any pictures of the rigid runways splitting?

Mr. KELLY. Yes, sir.

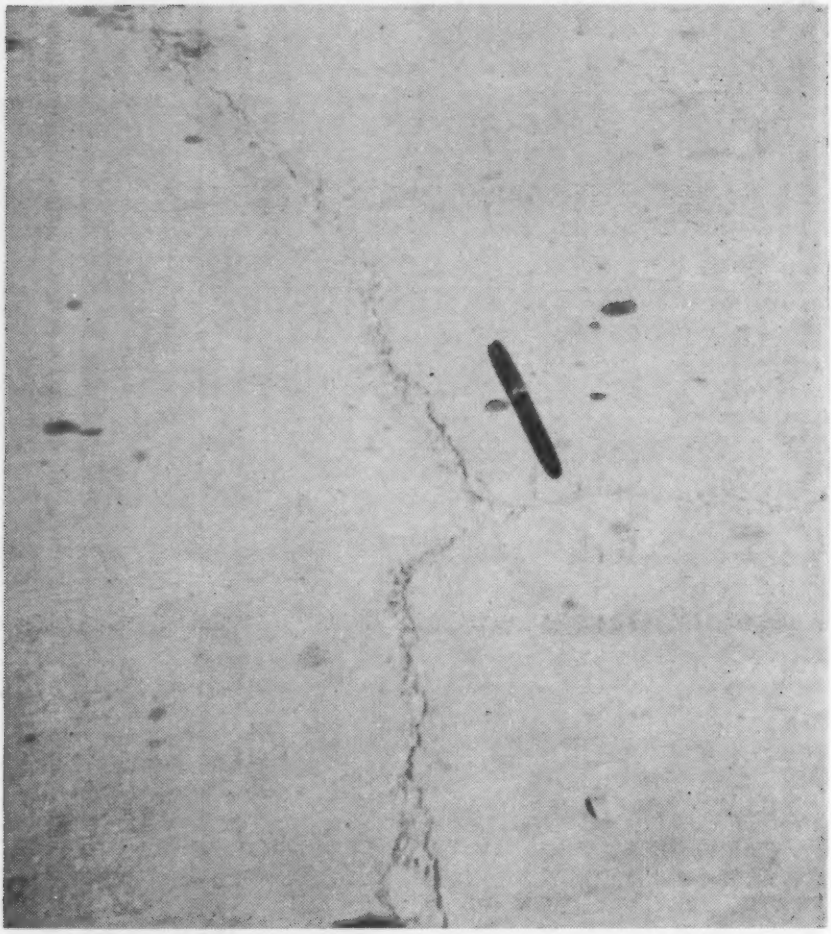
Mr. HÉBERT. May the committee have the benefit of those pictures?



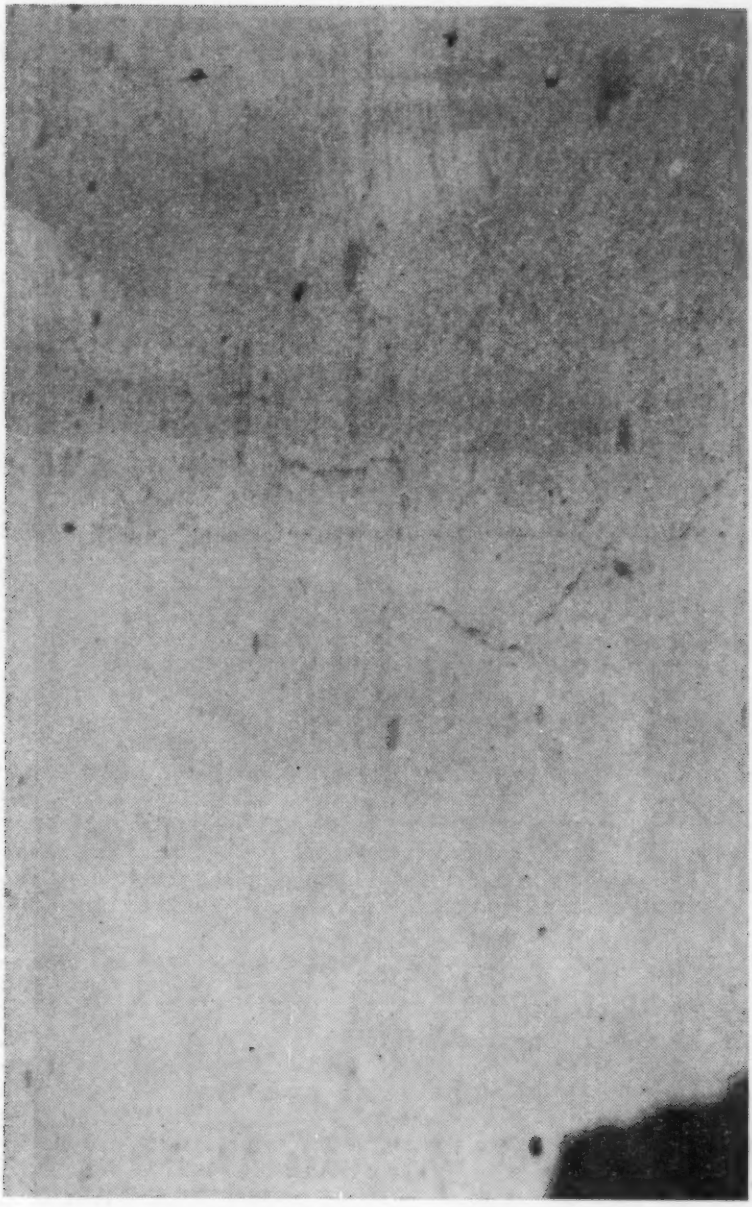
Random cracking in new concrete pavement—Primary taxiway. Columbus Air Force Base, Nov. 28, 1958.

Transverse structural crack in Portland cement concrete pavement. Extends into test lane from right side in vicinity of Sta. 85+37. Columbus AFB.

Transverse crack completely across slab. Right lane of finger on NW. end runway about Sta. 100+00. Columbus Air Force Base Nov. 28, 1958.



Cracks in new Portland cement concrete pavement of primary taxiway. Columbus AFB (on centerline, vicinity of Sta. 40.



Cracks in new Portland cement concrete pavement of primary taxiway. Columbus AFB (on centerline, vicinity of Sta. 40).

Cracks in new Portland cement concrete pavement of primary taxiway. Columbus AFB (on centerline, vicinity of Sta. 40).

Mr. KELLY. If I can present these to you? Theses pictures were taken at the time of the completion of the test at Columbus Air Force Base. They show fairly conclusively what happens to a rigid concrete paving slab that is subjected only to temperature, its own inherent characteristics, and light truck loading. In my opinion, having built a rigid runway for the Air Force——

Mr. HÉBERT. I want the record to show that I didn't know you had those pictures. [Laughter.]

Mr. GRIFFITH. Mr. Chairman, may I hand Mr. Hardy a picture that might answer one of the questions he asked a while ago. That picture was taken last Saturday, during a rainstorm, at Columbus Air Force Base. The person who took the picture was standing on the end of the concrete figure looking down the runway, and you will see to your right the test section that has undergone the test.

Mr. HARDY. Now this is after it was repaired.

Mr. GRIFFITH. But you must understand that it was repaired; yes, sir.

Mr. HARDY. What I would like to know now is whether or not you took any pictures of any concrete section down there after a rain?

Mr. KELLY. You will see one in here, sir.

Mr. HARDY. Have you any rain standing on it?

Mr. KELLY. Yes, sir; you will see a birdbath.

Mr. HÉBERT. An ode for a Solomon.

Mr. KELLY. I would like to continue to develop the apparent thing that in my opinion must happen now at Columbus Air Force Base. Those cracks are of such magnitude——

Mr. COURTNEY. You mean the concrete cracks?

Mr. KELLY. The concrete cracks are of such magnitude——

Mr. HARDY. You can patch them with asphalt, can't you?

Mr. KELLY. We can overlay it and there are contractors who would be happy to. That is one solution.

I doubt if that will be the accepted solution. They will probably come out of maintenance funds or change orders to correct them before the contract is accepted.

In the case that you mentioned, Duluth, which I happened to observe, at the Duluth Air Force Base the method of correcting the cracks there was to saw out large chunks of the concrete full depth and replace it with concrete. It is probably the only way you can repair a crack of that nature and magnitude.

Mr. COURTNEY. I don't want you to think that Minnesota is my private preserve.

Mr. HARDY. I do see, Mr. Chairman, a picture here that was obviously made after a rainstorm. But this one looks like it must have been more rain than the other.

I wonder if you had sent Mr. Kennedy a copy of this?

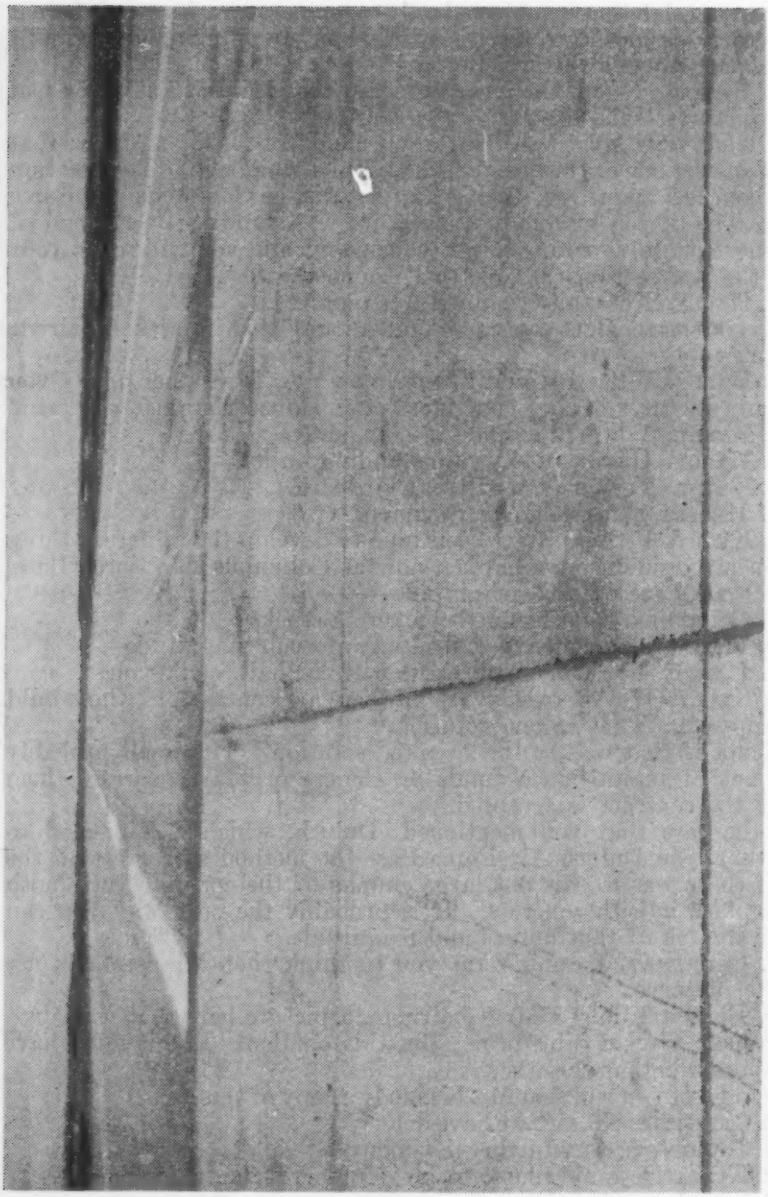
Mr. GRIFFITH. No, sir; we have not.

Mr. COURTNEY. Any further testimony?

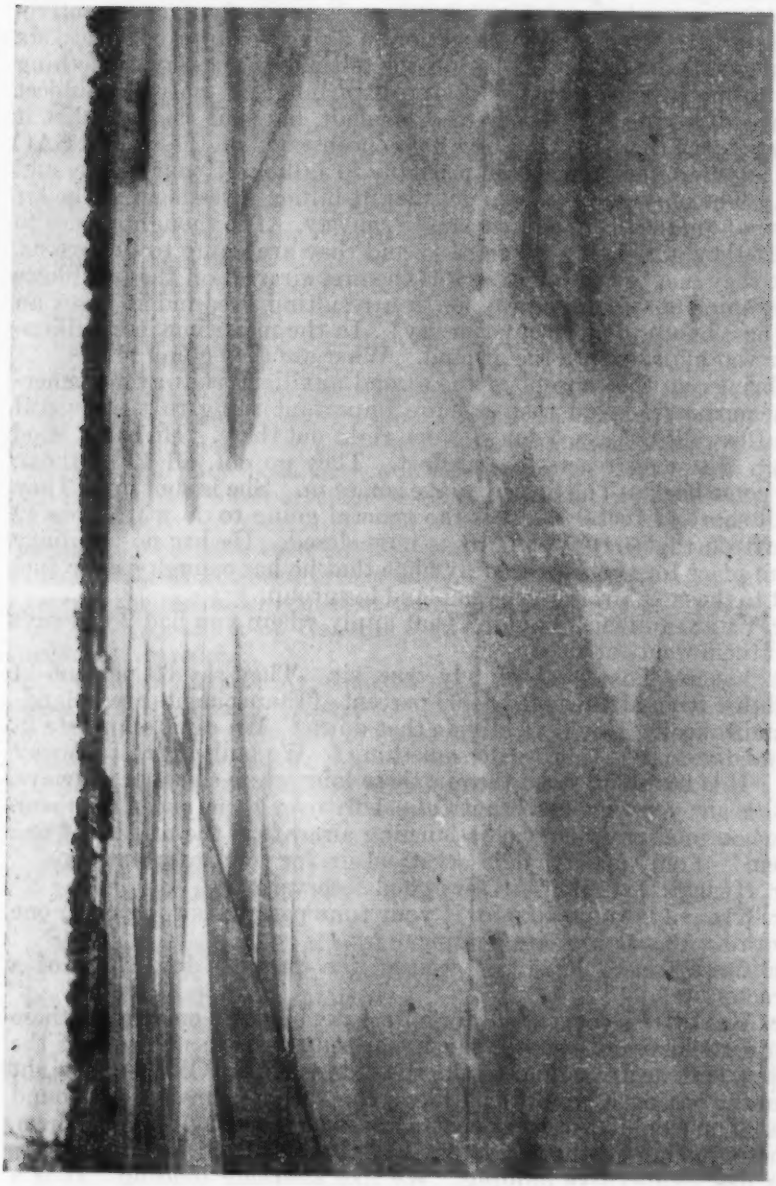
Mr. KELLY. I would like to make an observation, if possible——

Mr. COURTNEY. Yes, sir.

Mr. KELLY. Of something that has come to my attention in the nature of my business.



Test section 11/28/58 Columbus AFB. On concrete looking toward asphalt portion, immediately after heavy rain.



Old apron Columbus AFB. 11/28/58 2 hours after heavy rain.

I am a paving contractor, operating all over the southwestern part of the United States and the Republic of Mexico. I have built one of these large runways, with the concrete ends and the flexible interior. In getting around from job to job it is necessary to fly in an executive-type aircraft. Under my observation in flying are approximately six of the so-called SAC bases. After the testimony Tuesday, something came to my attention that is really disturbing, not only the subject of airfield paving with concrete or asphalt, but it is the fact that it appears to me that the Air Force has concentrated on these great SAC bases an effort that represents probably $1 billion of your money and mine. The only way they can get that $1-billion investment in the air in case of an alert is down one single runway. The thought comes to me: If they are sitting on an alert and they are going to protect us, aren't they in a pretty tough spot if the first aircraft off the line blows a tire, spins out on a runway, with a resulting fire, and it takes an hour or 2 hours to clear our runway? In the meantime, our billion-dollar war effort sets on the ground. What are they going to do?

It brings up the concept of the second auxiliary runway for emergency purposes. And then a more important thing to the general from Roswell Airbase. And I work right out there. He had a good point. His wing reacts to an effort. They go out, all 49 of them. They come back. The first airplane comes in. She is shot up. They are all short of fuel. What is the general going to do with those 49 aircraft on that 1 runway? It is now closed. He has no auxiliary and no place to go. He can only hope that he has enough gas or fuel to get to the next airbase so he can land his group.

Mr. CUNNINGHAM. Wouldn't that apply where you had 2 runways if 2 of them went out also?

Mr. KELLY. That is absolutely true, sir. They say 60 percent—I heard this from Mr. Kennedy—60 percent of the accidents are in landing and takeoff. Could we divide that down? We can't eliminate it. Can we divide it? Can we do something? We built a great runway here. It is beautiful from the air, these long white concrete runways. I will grant you they are beautiful. I fly over them and I see them. But what good are they with a burning aircraft in the middle of one of them? I only make that observation, sir, for your information.

Mr. HÉBERT. I think it is a very good observation.

Mr. KELLY. I would like to, if your time permits, sir, clear up one other thing about alternate bidding.

Mr. COURTNEY. I have just written the question down here of a contractor.

Mr. KELLY. If you called for alternate bidding on one of these major airfields—and we will say it happens to be in my part of the country, and we are going to take the bids at Tulsa, Okla.—the night before the letting it would look like a contractors' convention around there. You would have every contractor in the country, 15, 20 of them, up there putting all the effort they have into that bid.

We like competitive bidding. We like alternate bidding. It is a very common practice in our business. It gives the contractor the advantage of throwing his best shot. Maybe this job—I have a gravel pit to the exclusion of some other contract. On the next job I have some other source to the exclusion of some other contractor.

Let us have the initiative in going out and obtaining for you the lowest price that is possible. Don't restrict us. I have engineering staff in the field, core drills. You call one of these jobs up for letting, and we are out there after it.

If it is bituminous concrete, we would be particularly after it.

Mr. HÉBERT. You speak my language. I am listening attentively.

Well, thank you very much, gentlemen.

Mr. COURTNEY. No further questions.

Mr. Chairman, as I have indicated, the participants today are those who have commented at other times in the inquiries of the subcommittee, and who participated in and observed the Columbus test. They were advised of the test and also advised of the Navy conclusions which were sent to them at the request of the subcommittee. And as to them, there is a reservation of time for comment because of the late date at which they received the Navy information.

As I indicated, the record will be sent to the printer on December 20.

Mr. HÉBERT. If they want to avail themselves of replying, they may, within that time limitation.

Mr. COURTNEY. Now, Mr. Chairman, in addition to these gentlemen who have presented prepared statements, we have the benefit of the auditing and observations of the Bureau of Public Roads, whose representatives have been here and have otherwise observed the test, and those of the Department of Commerce, the Shell Oil Co., which has indicated an interest, as well as the Association of General Contractors, who have been advised and have received all of the documents which have been presented to the subcommittee, including the report, the technical report of the Columbus test.

The Association of General Contractors has indicated it had no comment to make.

As far as I know, Mr. Chairman, those are the only organizations, institutions, or associations, who have expressed an interest or who might have a contribution to make to the information which the subcommittee is assembling.

Does the Shell Oil Co. wish to be heard?

Mr. PARKER. My name is Thomas Parker. With me is Mr. Izatt.

We have no comments to make unless the committee has questions.

Mr. CUNNINGHAM. No questions.

Mr. COURTNEY. Then you don't desire to be heard?

Mr. PARKER. No, sir.

Mr. COURTNEY. With the addition of the supplemental information to be received, then, Mr. Chairman, that is all the information that is available to the subcommittee.

Mr. COURTNEY. That is all the information which is available to the subcommittee, or has been suggested for presentation.

Mr. HÉBERT. Thank you very much, gentlemen, who have cooperated with us.

The committee will stand adjourned, sine die.

(Whereupon, at 4 p. m., the committee adjourned.)

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APPENDIXES

APPENDIX A

DECEMBER 18, 1958.

Hon. F. EDWARD HÉBERT,
Chairman, Subcommittee for Special Investigations,
Committee on Armed Services, House of Representatives.

MY DEAR MR. HÉBERT: In my testimony before your subcommittee on December 5, 1958, I requested that the Asphalt Institute be permitted additional time to study the Department of the Navy Report on Rigid and Flexible Type Pavements for Naval and Marine Corps Stations, dated May 1958. I indicated at the time that we might wish to submit a statement regarding this report. You very kindly permitted us to submit such material on or before December 20, 1958. After a careful review of the report, we wish to offer comments as contained in the remainder of this letter.

Page 1 of the report establishes two classes of pavement loadings, designated as class 1 and class 2, used by the Navy. The last paragraph on this page concludes that:

"The requirements posed by classes 1 and 2 aircraft are easily met in the case of concrete pavement of adequate thickness, constructed on a firm, well-compacted subbase of adequate thickness and stability."

On page 3 of the report, it is noted that:

"Insofar as tire loads (pounds) and not tire pressures (pounds per square inch) are concerned, flexible-type pavements have been most adaptable to stage construction and it has been economical to overlay them progressively for progressively heavier aircraft."

It would thus appear that the statement quoted first above might be considered by the Navy to be equally true of asphaltic pavements with but two exceptions.

The principal exception seems to be what the Navy describes generally as a lack of "toughness" in asphalt mixes. There is no question but that asphalt pavements are suitable for the Navy's class 1 pavements. This was established by the Columbus Air Force Base tests, where both the load and tire pressure were in excess of those stipulated for the class 1 design. Therefore, the exception under discussion should be considered only in regard to class 2 Navy pavements.

As indicated in my testimony on December 5, 1958, the Asphalt Institute would welcome the opportunity of working with the Navy on a solution to the "toughness" problem. The pavements on which Army tanks are tested are asphalt concrete. These pavements have been designed and constructed to be "tough" enough to successfully withstand tearing by the track lugs when the tank is turned. We were happy to hear Admiral Peltier indicate that the Navy would maintain an open mind on such problems because we believe that some of our industry's experience in tank track design, warehouse floors, and other areas of high-loading intensity offer good possibilities for an adequate solution which will still be economical.

The other exception is mentioned at the top of page 2 of the report and relates to the solvent action of hydrocarbon fuels on asphalt pavements. The report goes on to state, however, that:

"The solvent action of hydrocarbon fuels is a problem of lesser importance." Discussions with Navy personnel and inspections of some of their airfields have led us to believe that solubility is no longer a problem except in refueling and repair areas. We had the impression that the Navy had given particular attention to the elimination of this problem because of the obvious fire hazards involved, particularly on aircraft carriers. We therefore believe that this exception should not be considered as a valid objection to asphalt pavements, except in refueling and repair areas where fuel spillage might occur. For such

areas, the asphalt industry has developed and now has under field test new resin admixtures which make the asphalt pavement highly resistant to heat and fuel solubility. These materials should be generally available in the near future.

Much of the Navy report is concerned with relative maintenance costs at Navy fields for portland cement concrete and asphalt pavements. At the top of page 6 it is noted that $639,438 was spent on the repair of portland cement concrete pavements and it is stated later than $2,488,581 was spent for repairs to asphalt-surfaced pavements during the same period of time. The report then goes on to state that the amount spent on asphalt pavements was "* * * about four times the amount spent on a greater yardage of concrete, considering the total yardage of each type of pavement at all airfields." This statement appears to be in conflict with the summary data shown on chart II and table I of the Navy report. Expenditures cited agree with totals shown on chart II. Table I, however, shows that for the airfields from which the cited maintenance costs were accumulated, the area of asphalt pavements is nearly twice that of portland cement concrete pavements. It would therefore appear that the statement quoted earlier in this paragraph is in error.

Maintenance figures contained in the Navy report prove rather conclusively that when maintenance is necessary on either type of pavement, unit repair costs for asphalt pavements are appreciably less than unit repair costs for portland cement concrete pavements. Summary data on chart II indicate that a total of $639,438 was spent to repair 1,836,134 square yards of portland cement concrete pavement; the unit repair cost thus being $0.348 per square yard. The same chart shows that $2,488,581 was spent to repair 8,801,103 square yards of asphalt pavement; the unit repair cost thus being $0.283 per square yard.

$$\frac{\$0.348}{\$0.283} \times 100 = 123.3 \text{ percent}$$

It is thus indicated that unit repair costs for portland cement concrete pavements average 23.3 percent above the unit repair costs for asphalt.

The need for continuous runway operation is apparent and it is agreed that it is desirable to have a pavement which will require a minimum time out of service for maintenance. The principal maintenance that might be required by a properly designed and constructed asphalt pavement is an occasional black seal of diluted asphalt emulsion to maintain surface impermeability and minimize oxidation effects on the drier mixes which might be encountered. For a runway 10,000 by 200 feet this seal, with only 2 modern asphalt distributors with 25-foot spreader bars which is standard for highway construction, requires less than 1 hour to apply. By starting in the center of the runway, the seal in the center should be dry enough for operation by the time the sides are covered. The sides should be usable in another hour. Assuming a reseal every 3 years, this makes a time out of service for maintenance of an average of 20 minutes per year.

On page 6 an argument advanced for portland cement concrete is that "very little equipment and few personnel" are required for joint filling. This is a rather far-fetched argument because only 1 man and 1 piece of construction equipment on almost any part of a runway will necessitate suspension of operations.

No methods and equipment have yet been developed to speed the cleaning and resealing of the joints in a portland cement concrete runway. This operation still requires much more time than it does to reseal an asphalt-paved runway. To replace a slab of portland cement concrete pavement requires much longer, to cut out the old concrete, pour the new, and permit curing of the new concrete. The Navy report points out on page 2 that "It is estimated that the minimum cost (to operations) of immobilizing an active major jet air station is $10,000 per day." Previously in this paragraph, the report states that "This greater cost is absorbed by naval operations and does not appear in the cost records that are usually kept for maintenance and repairs." Considering all of these factors, it appears that the unit cost of maintaining portland cement concrete is substantially greater than the 23.3 percent in excess of asphalt unit costs. The data are inadequate, however, to fully evaluate how much greater these costs may be.

It is rather difficult to understand why the Navy would be so perplexed in the patching of small areas of flexible pavement. Asphalt is available throughout

the world, meeting the standard specifications of the Asphalt Institute which have been adopted substantially by the American Society for Testing Materials, American Association of State Highway Officials, and standard Government specifications. Likewise, specifications for quality and graduations or asphalt aggregate have been standardized by these agencies, and aggregates meeting these specifications are normally available within short haul of any naval air station in the United States and can be supplied and stocked for overseas stations. Modern, high-quality, efficient, hot-mix asphalt plants are within reasonable hauling distance of any air station in the United States. These plants can immediately adjust their operations to provide any specified mixture. It is hard to understand why an engineering organization like the Navy Bureau of Yards and Docks would have to consider employing a commercial testing laboratory to design a mixture for 30 cubic yards of asphaltic concrete. After the design has been established for aggregate available at a given plant, it is only necessary to specify the same design each time small quantities are ordered for maintenance purposes. Asphalt and aggregates for asphalt mixes are just as much "standard products" as portland cement and aggregates for portland cement concrete. The report dwells at length on the scarcity of aggregate adequate for high-stability asphaltic concrete. It might be interesting to note that standard specifications such as those of the American Society for Testing Materials, American Association of State Highway Officials, and the standard Government specifications have no essential difference in their requirements for aggregate for asphaltic concrete and for portland cement concrete. Qualitywise, the requirements are essentially the same. The only differences are in gradation for the different type mixtures.

The reports from the 42 naval air stations covered in Summary of Reports in enclosure 1, pages 1 to 4, on careful analysis do not substantiate the drastic statements in the text of the report under The Service Record of Asphalt-Surface Pavements, pages 3, 4, and 5. The most probable damage to a pavement by high-pressure tires and heavy loads is "abrasion and scuffing," "rutting," and "raveling."

Analysis of the reports pertaining to these damages reveals that of the 42 naval air stations only 2 reported any serious abrasion and scuffing, while 3 classified skid marks and pitting as abrasion and scuffing.

Likewise, only 1 of the 42 stations reported "serious rutting." Five reported "none," 4 reported "slight," while over half of them (23) apparently could not find rutting, so showed "not reporting." The only rutting another naval air station could find were "grooves cut by tail skids or hooks."

Likewise, under raveling, only 1 of the 42 reported "serious raveling," while another found a spot at "east edge of runway 14 near intersection with runway 19." One naval air station reported "minor raveling," 2 reported "none," and 26 others under raveling showed "not reported." Another found some raveling caused by operation of arresting gear.

Although the Asphalt Institute does not have the construction history of airfields listed in the report, it would appear that a statement at the bottom of page 3 may be misleading. This statement is: "These pavements have been constructed subsequently to 1950 and the surfacings are of superior type of asphaltic concrete of high Marshall-test stability, made with densely graded, hard, and durable aggregates and asphalt cement."

The statement seems to imply that the entire pavement structure for all facilities listed in the report have been constructed since 1950. We believe it likely, however, that only relatively thin asphalt surfaces have been placed in most of these locations. If this is the case, it would be highly questionable whether the base and other supporting elements were compacted to a sufficient degree to withstand the higher stresses imposed by the more severe loading conditions. It would be interesting to know if the Bureau of Yards and Docks required additional compaction of these structures prior to resurfacing them with asphalt.

Respectfully submitted.

ARVIN S. WELLBORN, *Chief Engineer.*

APPENDIX B

REPORT ON OBSERVATIONS OF FLEXIBLE PAVEMENT TEST SECTION, COLUMBUS AIR FORCE BASE, MISS.

For: National Bituminous Concrete Association.
At request of: Mr. H. K. Griffith, executive director.
By: W. B. Warden and S. B. Hudson, Miller-Warden Associates, Swarthmore, Pa.
Date: December 8, 1958.
Subject: Summary of observations of construction and testing at Columbus and related comments on testimony given before Committee on Armed Services, Special Subcommittee for Investigation, in the matter of airstrip paving, December 2 and 5, 1958.

BACKGROUND

In accordance with your instructions we have closely followed the design, construction, and testing of the flexible pavement test section located at Columbus Air Force Base, Columbus, Miss. Our representatives attended and testified at the hearings in 1957. We attended the Vicksburg and Atlanta conferences and reviewed the Corps of Engineers specifications for this project issued October 21, 1957. Our engineers have observed every phase of the construction of the test section, have studied the results of material tests made by the Corps of Engineers, and have made independent tests on samples of the actual pavement made available to us by the corps. We have observed the accelerated traffic test from the first to the final application of load and the subsequent condition of the pavement after the seal coating. The results of our independent studies and observations are contained in the detailed reports which have been submitted periodically and are summarized below. These various detailed periodical technical reports are a matter of record on file in both the NBCA office in Washington and our office in Swarthmore and could be made available to the committee upon request, if desired.

OBSERVATIONS OF CONSTRUCTION

It is our opinion that the construction of the flexible pavement was carried on under typical job conditions and that it is entirely practical to duplicate the construction at other locations. Construction conditions were average rather than ideal. The native soil at this location contains considerable desirable granular material, but the clay content made compaction difficult under the heavy rainfall conditions which prevailed during the entire construction period. The local aggregates which were used in the bituminous concrete, although meeting specification requirements, do not compare favorably with those available in other areas. Our analyses of the bituminous pavement indicate that the asphalt cement used was of good commercial quality and was not excessively hardened. Except for the reduced asphalt content, the bituminous concrete was representative of that generally used for paving purposes.

OBSERVATIONS OF TESTING

We are in general concurrence with the Corps of Engineers in the interpretation of the observations directly connected with the test. However, it is our opinion that the longitudinal cracking noted intermittently in the test section was influenced by the peculiarities of the test and would not have occurred if the bituminous concrete had been subjected to normal traffic distribution which would not have introduced the tensile stresses into the pavement which existed under the test conditions.

We also are of the opinion that the deformation noted along the inside edges of the test lane was influenced by the traffic pattern used.

The deformation of the pavement noted in the vicinity of station 84+88 was probably influence by the action of the buried slab, which moved as the test load rolled across this point. This depression was of limited area and would normally be repaired under ordinary maintenance procedures.

The maintenance of proper voidage in the bituminous concrete under the simulated B–52 traffic was one of the important quality attributes of the bituminous pavement which was tested. Our independent analysis of pavement samples, by another method than that used by the corps, is in very close agree-

ment with the reported results with respect to changes in voidage. From a technical standpoint we believe it is important to emphasize that this test shows that bituminous pavement can be built under current criteria and average construction conditions which will maintain voidage under the traffic of very heavy wheel loads at high tire pressures.

RESULTS

The test was designed to evaluate the suitability of flexible pavement constructed under actual field conditions in accordance with current Corps of Engineers specifications for heavy-load runway pavement. In our opinion the results of the test indicate the suitability of the flexible pavement for such usage.

We concur with the conclusion of the corps that under normal traffic distribution the pavement deformation would be within acceptable limits and are of further opinion that the minor cracking intermittently observed would not have occurred under actual conditions of location and traffic.

We believe that the design of the buried slab can be improved and that pavement deformation adjacent to the concrete-asphalt junction can be minimized, if movement of the buried slab can be restrained. We do not have data on the elastic recovery of the pavement since the conclusion of the test but have observed that since the application of the sand seal coat the deformation of the pavement is not now sufficient to retain water during a rain.

COMMENTS ON TESTIMONY

The use of the runway for a taxiway for extended periods is a speculative concept which has not appeared in connection with runway pavement problems until the present hearings. The projection of the test results to the conclusion that such usage would result in objectionable differential settlement appears to be largely conjectural. It may equally well be conjectured that due to the higher rate of travel of actual aircraft during takeoff or taxiing on the runway the pavement deformation would be less than that observed under the test conditions. In any case, due to differences in traffic distribution patterns, the effect on runway pavement of taxiing, aborted takeoffs or Cocoa alerts is not directly comparable to the effect of narrowly channelized traffic on taxiway pavement.

We question whether the continuous concrete strip down the center of the runway is good insurance for overall runway smoothness. As pointed out in other testimony the longitudinal joint between two types of materials is difficult to construct and maintain. Also, as stated in Air Force IECM58, practical construction difficulties are encountered in the field because portland cement concrete tends to slump after placement, etc. This results in surface irregularities which place definite limitations on the smoothness which may be obtained with rigid pavement. This was recognized by Air Force IECM of June 1958 which relaxed the smoothness tolerances from the original requirements. At Columbus it was noted that the smoothness of the flexible pavement was decreased at the juncture with the rigid pavement due to the necessity of meeting the grade of the concrete at all points along the longitudinal joint. Further, normal maintenance procedures would be expected to retain the smoothness of properly constructed flexible pavement over the years, whereas normal maintenance of the joints plus the additional warpage, cracking, and spalling of the rigid concrete slabs would probably impair the smoothness of these surfaces over years of service.

We feel that the suggested 75-foot strip concrete finger down the center of the runway is structurally unnecessary and may well constitute an operational hazard within a few years as well as imposing undesirable complications during construction.

One point of pertinent testimony was not sufficiently emphasized in the recent hearings, in our opinion. In the January 1958 testimony it was agreed by all that the 75-foot concrete finger was a construction expedient for Columbus Air Force Base only and would not establish a precedent for future construction. At this time it was specifically stated by Mr. Ferry, representing the Air Force, that this test was for the purpose of establishing whether or not asphaltic pavement over a period of years can withstand the heavy traffic loads imposed and that otherwise the two types of pavement were considered to be equal; that "* * * as far as our records are concerned, we (the Air Force) are unable to

determine any difference in fact or of increased hazard with either paving." The observations of our staff and affiliate engineers and their discussions with SAC pilots at many of the United States and foreign bases confirms this statement. In view of this rather positive position established by Air Force records as late as January of this year and the agreed success of the Columbus test plus the successful operations at Loring Air Force Base and elsewhere on flexible pavement runways, much of the conjectural testimony in the recent hearings would not seem to warrant further comment from the engineering viewpoint.

With respect to the testimony of the Navy regarding surface toughness we concur that the ability of flexible pavement to be designed and constructed to take the traffic of the highest tire pressures in actual use on Navy planes should be demonstrated. We have no information as to the availability of 400 p. s. i. tires but experience with solid rubber tires and steel-wheeled traffic on industrial floors indicates that bituminous surfacing materials of the type successfully used for these industrial applications may be suitable for the Navy usage, if the incentive for such developments exists. Preliminary testing by the Navy on the Columbus test section might also be enlightening.

CONCLUSIONS

Based on direct observation of both the construction and the testing at Columbus and on careful perusal of the corps data and on independent analyses and testing of pavement cores, it is our finding that:

The Columbus test substantiated the adequacy of the Corps of Engineers design of flexible pavement for B–52G interior runway service and the ability of both engineers and contractors to construct a pavement to this design under practical working conditions.

It is our opinion that:

1. The proposed 75-foot Portland cement concrete finger is not good engineering and may actually increase operational hazard.
2. The ability of flexible pavement to withstand the highest tire pressures in actual use on Navy planes is subject to question and needs to be demonstrated by appropriate tests.
3. The recent IECM 58–11 revision[1] to Air Force policy with respect to type of airfield pavement should be rescinded on the basis of the findings of the Columbus test.

Modification to permit alternate methods of construction based on competitive bidding should result in substantial economies and preserve the incentive for further research and improvement.

APPENDIX C

HEADQUARTERS, DEPARTMENT OF THE ARMY,
OFFICE OF THE CHIEF OF ENGINEERS,
Washington, D. C., December 30, 1958.

Mr. JOHN J. COURTNEY,
Special Counsel, Subcommittee for Special Investigations,
Committee on Armed Services, House of Representatives.

DEAR MR. COURTNEY: In answer to a telephone request of your Mr. Kuhn on December 18, the following information is presented relative to the exact location of the defective rigid pavement at Grand Forks and Duluth Air Force Bases and the extent to which remedial repairs of the defects may have affected Air Force operations or occupancy. This information supplements that furnished the subcommittee by the Portland Cement Association in their letter of December 15, 1958.

Duluth Air Force Base.—The cracking occurred in the primary runway in a random pattern without distinction of area (interior versus ends). Cracking

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[1] This revision is Installations Engineering Criteria Memorandum 58–11, which states: "Primary use pavement at all Air Force installations will normally be constructed of portland cement concentrate." The term "primary use pavement" as defined therein as "all runways having adequate length, width, and approaches to permit sustained use by combat and combat supported aircraft" in addition to the so-called critical areas. IECM 58–11 was implement in April 1958 for "immediate application and will be integrated into fiscal year 1958 supplemental MCP, fiscal year 1959 MCP, and future construction programs."

was related to local climatic conditions, and the problem was eliminated by changing the jointing and curing methods. Cracked slabs were removed and replaced without delay in BOD or interference to Air Force operations.

Grand Forks Air Force Base.—The structural cracking in the portland cement concrete pavements at this base is confined generally to the westerly half of the 300-foot width of the runway between stations 75+00 and 97+00 (in the runway interior) and in the easterly third of the SAC operational apron. As reported by the Portland Cement Association, based upon information furnished by the Chief of Engineers, 138 slabs have shown structural distress in the form of cracking out of a total of 7,740 slabs placed in these specific pavement features. Recent condition survey information, which was not available to the PCA at the time of their inquiry, has been received from our Missouri River division engineer. These data show that some 42 additional cracks exist at random locations in the remaining pavement facilities outside the two areas mentioned, bringing the total crack count to 180 slabs or slightly more than 1 percent of all slabs placed on the entire airfield.

While frost heave is considered the major cause of the cracking, other factors such as temperature differentials during placement, delayed sawing, and possibly swelling clays in the foundation may also have contributed to the distress. The Corps of Engineers has installed instrumentation in selected areas and will continue to make observations during and following the next freezing season in an effort to definitely establish the cause of the distress.

The BOD of the airfield was not affected by the pavement cracking or the remedial crack sealing that has been accomplished. The pavements are considered structurally adequate to safely support the aircraft operations for which designed.

Sincerely yours,

E. E. WILHOYT, Jr.,
Colonel, Corps of Engineers,
Acting Assistant Chief of Engineers for Military Construction.

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